Deep Learning In OpenCV

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Agenda

- Background information
- OpenCV DNN module
- OpenCL acceleration
- Vulkan backend
- Sample

What is OpenCV?

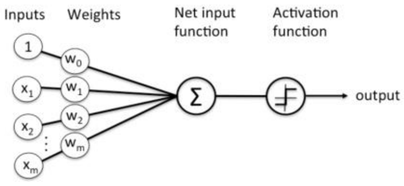
- Open Source Compute Vision (OpenCV) library
- 2500+ Optimized algorithms used for compute vision and machine learning
- C/C++/Python compatible and cross platform
- 20000+ forks in GitHub

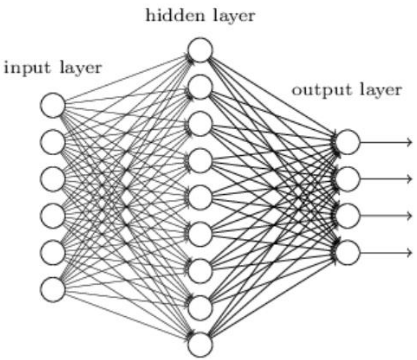
What is OpenCV?

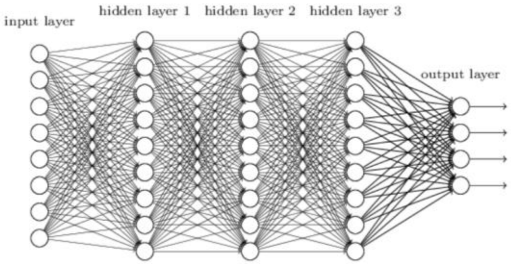
- OpenCV 4.0 released on Nov 2018
  - Switch to C++ 11
  - Most C APIs removed
  - No longer binary-compatibility
  - Better performance on CPU (AVX2)
  - Compact footprint
  - OpenVINO backend for DNN

Key concepts of Deep Neural Networks (DNN)

- Node/Layer/Network/Deep Neural Networks







Node/Neuron/Perceptron

Layer

Deep Neural Network

Key concepts of Deep Neural Networks (DNN)

- Training

  step1. set training parameters, e.g. learning rate, batch size, loss function, weight initialization.

  step2: set input data (e.g. an image) and forward computation

  step3: compare the forward result and the ground truth and calculate the error

  step4: Backpropagation and go to step 2 until the error is small enough

Complicated?
Deep Learning Frameworks will do that for you

TensorFlow Caffe torch

Key concepts of Deep Neural Networks (DNN)

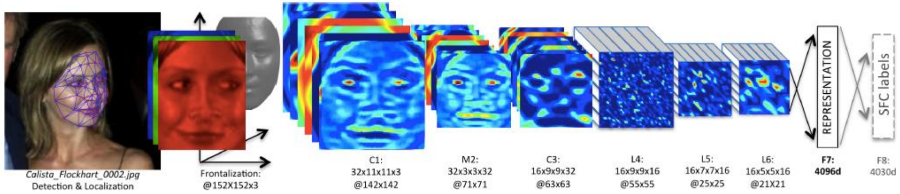
- Inference

  You have a trained model, look it as a function.

  Set input data and compute the network output using deep learning library.

  Done!

- Use case



OpenCV DNN module

- Included in OpenCV main repo since version 3.3
- Inference only
- Compatible to many popular Deep Learning frameworks

OpenCV DNN module

Why we need a new wheel of DNN in OpenCV?

- Lightness

  - inference only can simplify the code, reduce compilation and runtime overhead

- Convenience

  - build-in cpu/gpu acceleration implementation, minimum external dependency

  - easy to add deep networks support to your existed OpenCV project

- Universality

  - Unified interface to manipulate net models from different deep learning frameworks

  - Support multiple target device and OS

    Device: CPU, GPU, VPU OS: Linux, Windows, Android, MacOS

OpenCV DNN module

- Support ~40 layer types

- AbsVal
- AveragePooling
- BatchNormalization
- Concatenation
- Convolution (including dilated convolution)
- Crop
- Deconvolution, a.k.a. transposed convolution or full convolution
- DetectionOutput (SSD-specific layer)
- Dropout
- Eltwise (+, *, max)
- Flatten
- FullyConnected
- LRN
- LSTM
- MaxPooling
- MaxUnpooling
- MVN
- NormalizeBBox (SSD-specific layer)
- Padding
- Permute
- Power
- PReLU (including ChannelPReLU with channel-specific slopes)
- PriorBox (SSD-specific layer)
- ReLU
- RNN
- Scale
- Shift
- Sigmoid
- Slice
- Softmax
- Split
- TanH

OpenCV DNN module

- Network well tested
  - AlexNet
  - GoogLeNet v1 (also referred to as Inception-5h)
  - ResNet-34/50/...
  - SqueezeNet v1.1
  - VGG-based FCN (semantical segmentation network)
  - ENet (lightweight semantical segmentation network)
  - VGG-based SSD (object detection network)
  - MobileNet-based SSD (light-weight object detection network)

Architecture of DNN module

Language Bindings
(Python, Java)

Accuracy test, Perf test, Samples

Top-level C++ API: Load a net model, network inference, retrieve network outputs …

Implementation level: model importers ,DNN engine, layer implementations

Acceleration Layer

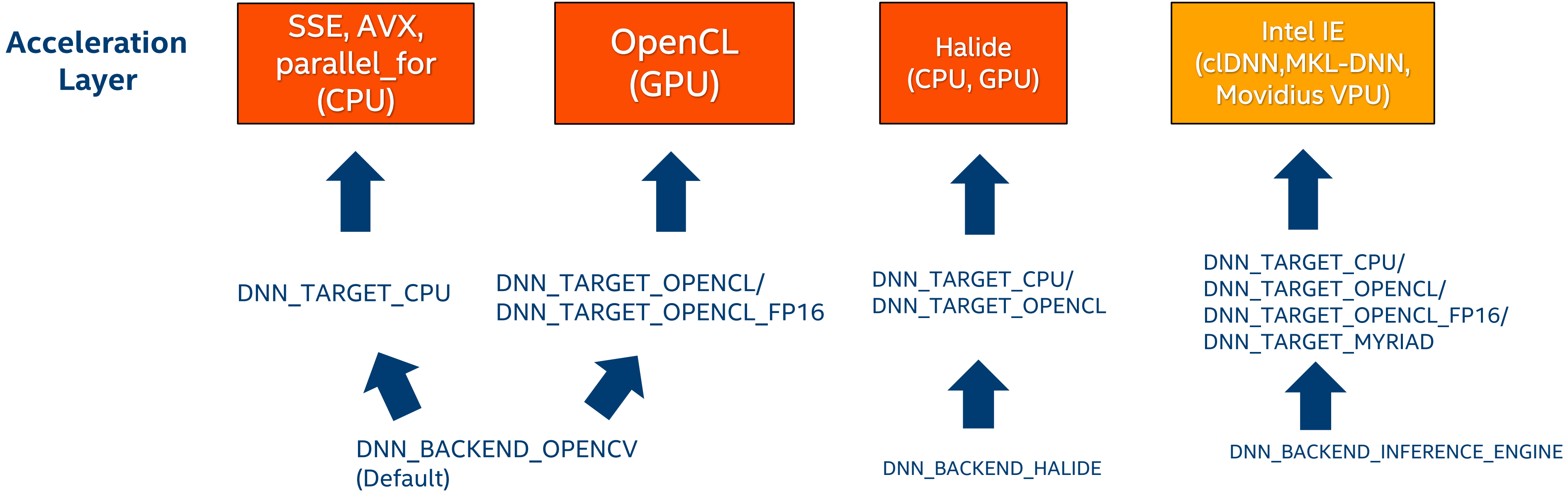
SSE, AVX, parallel_for (CPU)

OpenCL (GPU)

Halide (CPU, GPU)

Intel IE (clDNN, MKL-DNN, Movidius VPU)

Backend and target



E.g. use Movidius VPU to accelerate.

setPreferableBackend(DNN_BACKEND_INFERENCE_ENGINE)
setPreferableTarget(DNN_TARGET_MYRIAD)

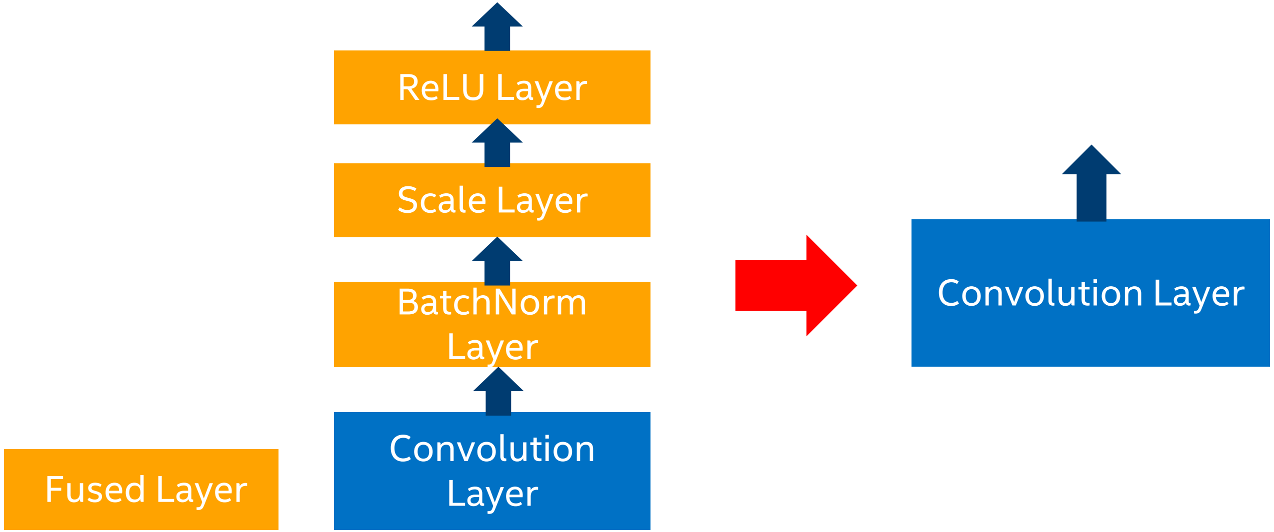
Network optimizations

- Thanks to internal implementation of deep network, these optimizations are not tied to any specific Deep Learning Frameworks.

- Benefit all the net models no matter what their original framework is.

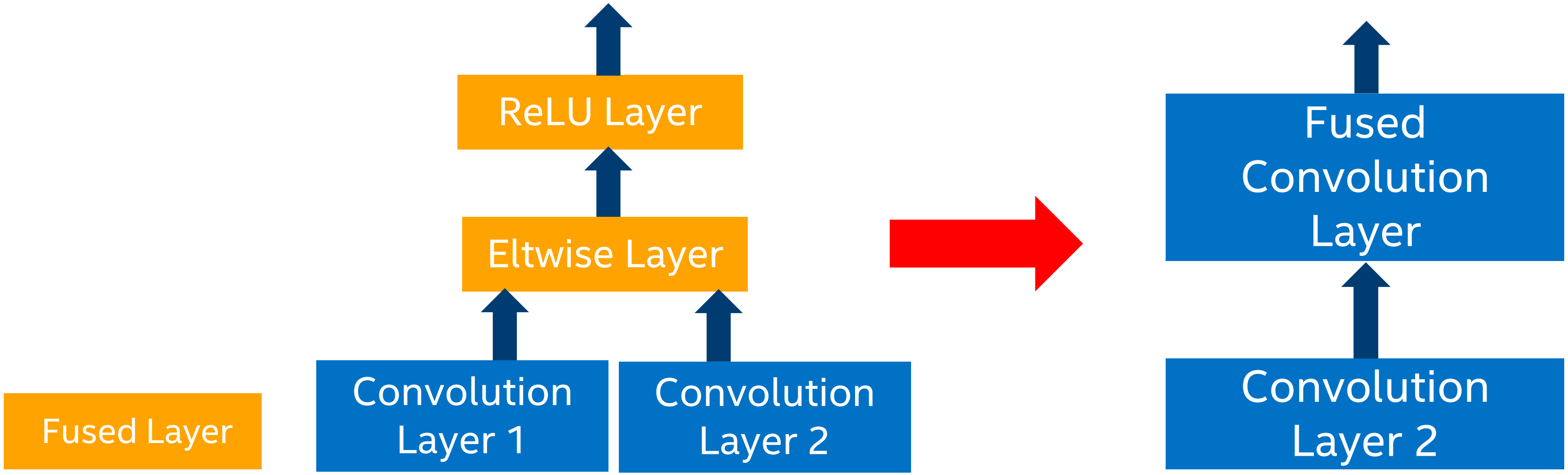
Layer Fusion

DNN module analysis network structure and, if possible, merge some layers into another one. This can reduce network complexity and computation workload.



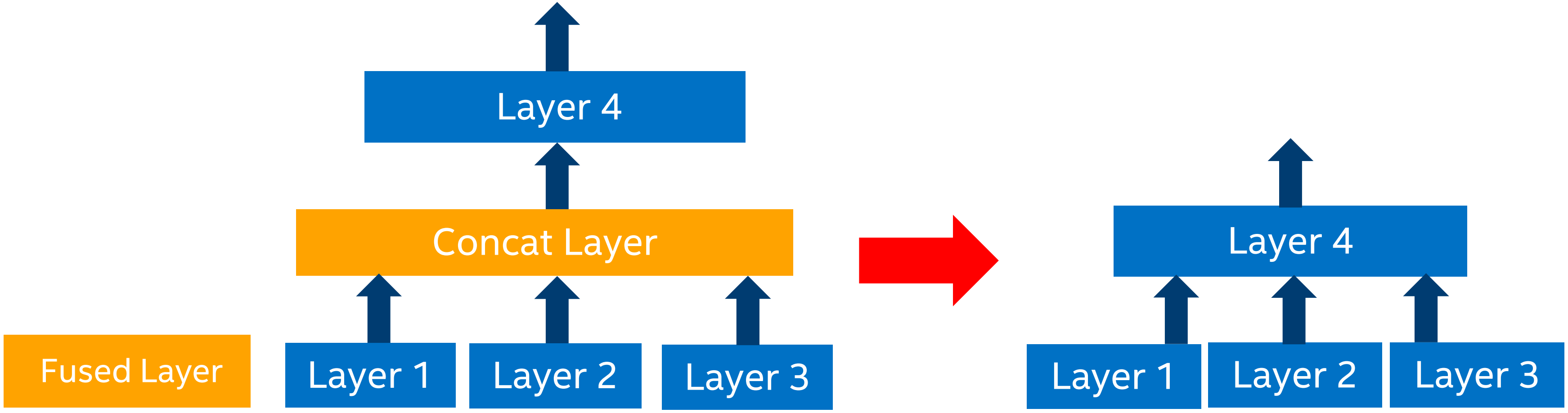
structure in ResNet50

Layer Fusion



structure in ResNet50

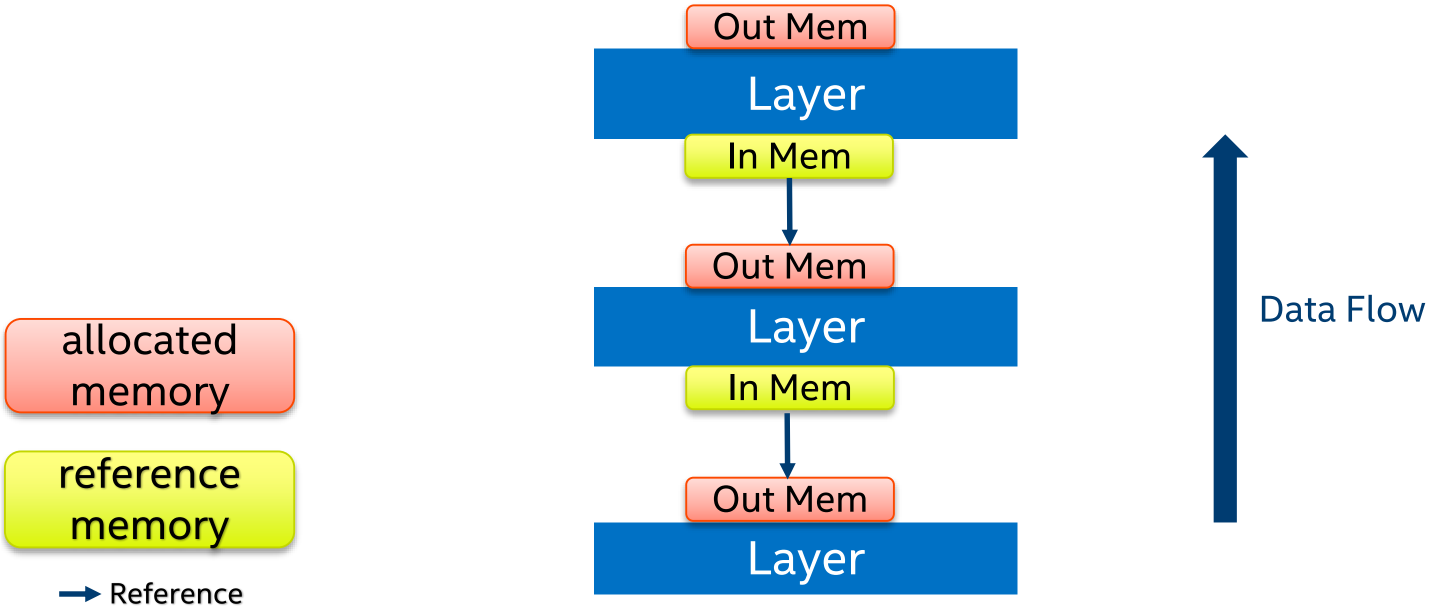
Layer Fusion



structure in SSD

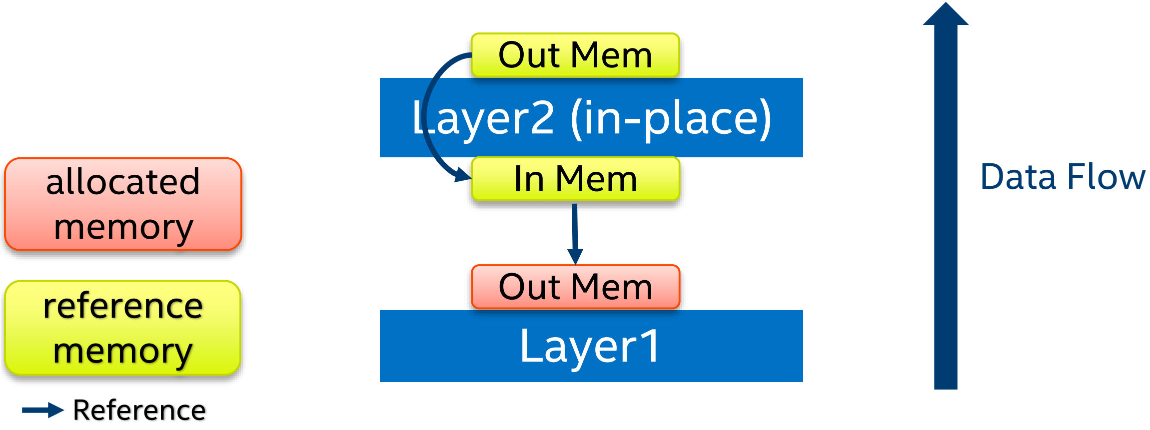
Memory reuse

- memory usage without reuse



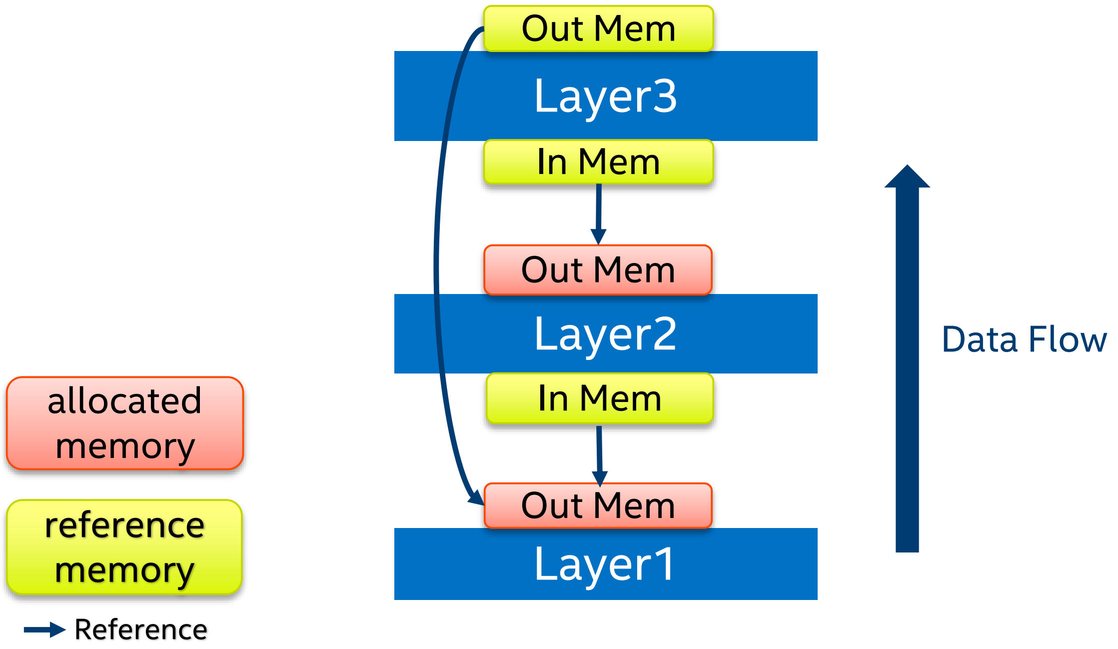
Memory reuse

- Reuse input memory



Memory reuse

- Reuse memory allocated at lower layer



OpenCL acceleration

- Build-in implementation, no external dependency except for OpenCL runtime
- Support FP 32 and FP16 data format
- Enable OpenCL acceleration

  setPreferableBackend(DNN_BACKEND_OPENCV)

  setPreferableTarget(DNN_TARGET_OPENCL)

  or setPreferableTarget(DNN_TARGET_OPENCL_FP16)

OpenCL acceleration

- Highly optimized convolution kernels
  - auto-tuning to find the best kernel configurations for a specific GPU
  - A set of pre-tuned kernel configurations built in the library
  - Tuning your own convolution kernel

    If you want to get the best performance for your GPU,

    try to run auto-tuning instead of using the default configurations.
  - How to enable auto-tuning?

    "export OPENCV_OCL4DNN_CONFIG_PATH=/path/to/config/dir"

    If you enable auto-tuning, the first time running a net model will be a little bit long.

    Next time, DNN module will use the cached configs directly and no need tuning again.

OpenCL acceleration

- For better performance on Intel GPU, use Neo driver

  - Neo is the open-source OpenCL driver for Intel GPU

  - Supported Platforms

    Intel Core Processors with Gen8 graphics devices (formerly Broadwell) - OpenCL 2.1

    Intel Core Processors with Gen9 graphics devices (formerly Skylake, Kaby Lake, Coffee Lake) - OpenCL 2.1

    Intel Atom Processors with Gen9 graphics devices (formerly Apollo Lake, Gemini Lake) - OpenCL 1.2

  - Use the version as new as possible

    new version always has better performance

OpenCL acceleration

- Performance Data (in milliseconds):

Model	DNN, C++	DNN, OpenCL
AlexNet	19.32	11.83
GoogLeNet	23.08	8.20
ResNet-50	53.26	15.74
SqueezeNet V1.1	5.94	2.60
Inception-5h	24.30	9.27
Enet @ 512*256	68.26	17.26
OpenFace(nn4.small2)	17.47	4.02
MobileNet-SSD @ 300*300 20 classes Caffe	30.89	8.71
MobileNet-SSD v2@ 300*300 90 classes, TensorFlow	47.57	15.40

Configuration:
OS: Linux 4.16.0 x86_64 (Ubuntu 16.04)
Compiler: c++ 5.4.0
OpenCV: 3.4.3-308-g761c269
CPU: Intel(R) Core(TM) i7-6770HQ CPU@2.60GHz x8
GPU: Intel® Iris™ Pro Graphics 580 (Skylake GT4e, 72EUs)

For more performance data, see:
https://github.com/opencv/opencv/wiki/DNN-Efficiency

Vulkan backend

- Landed in OpenCV 4.0

  https://github.com/opencv/opencv/pull/12703

dnn: Add a Vulkan based backend #12703

Edit

Open wzw-intel wants to merge 5 commits into `opencv:master` from `wzw-intel:vkcom`

Conversation 12 | Commits 5 | Checks 0 | Files changed 88 | +16,680 −11

wzw-intel commented 12 days ago • edited | Contributor

This commit adds a new backend "DNN_BACKEND_VKCOM" and a new target "DNN_TARGET_VULKAN". VKCOM means vulkan based computation library.

This backend uses Vulkan API and SPIR-V shaders to do the inference computation for layers. The layer types that implemented in DNN_BACKEND_VKCOM include: Conv, Concat, ReLU, LRN, PriorBox, Softmax, MaxPooling, AvePooling, Permute

This is just a beginning work for Vulkan in OpenCV DNN, more layer types will be supported and performance tuning is on the way.

Reviewers

alalek

Assignees

No one assigned

Labels

category: dnn

feature

Milestone

No milestone

Vulkan backend

- Enable Vulkan backend

  setPreferableBackend(DNN_BACKEND_VKCOM)

  setPreferableTarget(DNN_TARGET_VULKAN)

- Extend the usage of GPU acceleration for DNN module

Sample: real-time objection detection with MobileNet-SSD

```python
import cv2

prototxt = "MobileNetSSD_deploy.prototxt"
weights = "MobileNetSSD_deploy.caffemodel"
input_h = 300
input_w = 300
thr = 0.5
mean_value = 127.5
classNames = { 0: 'background', 1: 'aeroplane', 2: 'bicycle', 3: 'bird', 4: 'boat',
               5: 'bottle', 6: 'bus', 7: 'car', 8: 'cat', 9: 'chair',
               10: 'cow', 11: 'diningtable', 12: 'dog', 13: 'horse', 14: 'motorbike',
               15: 'person', 16: 'pottedplant', 17: 'sheep', 18: 'sofa', 19: 'train', 20: 'tvmonitor' }

# Open camera
cap = cv2.VideoCapture(0)

# Load net model
net = cv2.dnn.readNet(prototxt, weights)
while True:
    # Read image, preprocess, set network input and inference
    ret, frame = cap.read()
    frame_resized = cv2.resize(frame,(input_h, input_w))
    blob = cv2.dnn.blobFromImage(frame_resized, 1/mean_value, (input_h, input_w),
                                 (mean_value, mean_value, mean_value), False)
    net.setInput(blob)
    detections = net.forward()
    # Done!

    # Draw bounding box, class name and confidence
    for i in range(detections.shape[2]):
        confidence = detections[0, 0, i, 2]
        if confidence > thr:
            xLeftBottom = int(detections[0, 0, i, 3] * input_w)
            yLeftBottom = int(detections[0, 0, i, 4] * input_h)
            xRightTop   = int(detections[0, 0, i, 5] * input_w)
            yRightTop   = int(detections[0, 0, i, 6] * input_h)
            heightFactor = frame.shape[0]/300.0
            widthFactor = frame.shape[1]/300.0
            xLeftBottom = int(widthFactor * xLeftBottom)
            yLeftBottom = int(heightFactor * yLeftBottom)
            xRightTop   = int(widthFactor * xRightTop)
            yRightTop   = int(heightFactor * yRightTop)
            cv2.rectangle(frame, (xLeftBottom, yLeftBottom), (xRightTop, yRightTop), (0, 255, 0))
            class_id = int(detections[0, 0, i, 1])
            if class_id in classNames:
                label = classNames[class_id] + ": " + str(confidence)
                labelSize, baseLine = cv2.getTextSize(label, cv2.FONT_HERSHEY_SIMPLEX, 0.5, 1)
                yLeftBottom = max(yLeftBottom, labelSize[1])
                cv2.rectangle(frame, (xLeftBottom, yLeftBottom - labelSize[1]),
                                     (xLeftBottom + labelSize[0], yLeftBottom + baseLine),
                                     (255, 255, 255), cv2.FILLED)
                cv2.putText(frame, label, (xLeftBottom, yLeftBottom),
                            cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 0, 0))
    # Display
    cv2.namedWindow("frame", cv2.WINDOW_NORMAL)
    cv2.imshow("frame", frame)
    if cv2.waitKey(1) >= 0: break
```

Sample: real-time objection detection with MobileNet-SSD

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# Open camera
cap = cv2.VideoCapture(0)
```

Sample: real-time objection detection with MobileNet-SSD

Few lines of code to introduce DNN functionality

```
# Load net model
net = cv2.dnn.readNet(prototxt, weights)
while True:
    # Read image, preprocess, set network input and inference
    ret, frame = cap.read()
    frame_resized = cv2.resize(frame,(input_h, input_w))
    blob = cv2.dnn.blobFromImage(frame_resized, 1/mean_value, (input_h, input_w), (mean_value, mean_value, mean_value), False
    net.setInput(blob)
    detections = net.forward()
    # Done!
```

Sample: real-time objection detection with MobileNet-SSD

Draw bounding box, class name and confidence and display

```
# Draw bounding box, class name and confidence
for i in range(detections.shape[2]):
    confidence = detections[0, 0, i, 2]
    if confidence > thr:
        xLeftBottom = int(detections[0, 0, i, 3] * input_w)
        yLeftBottom = int(detections[0, 0, i, 4] * input_h)
        xRightTop   = int(detections[0, 0, i, 5] * input_w)
        yRightTop   = int(detections[0, 0, i, 6] * input_h)
        heightFactor = frame.shape[0]/300.0
        widthFactor = frame.shape[1]/300.0
        xLeftBottom = int(widthFactor * xLeftBottom)
        yLeftBottom = int(heightFactor * yLeftBottom)
        xRightTop   = int(widthFactor * xRightTop)
        yRightTop   = int(heightFactor * yRightTop)
        cv2.rectangle(frame, (xLeftBottom, yLeftBottom), (xRightTop, yRightTop), (0, 255, 0))
        class_id = int(detections[0, 0, i, 1])
        if class_id in classNames:
            label = classNames[class_id] + ": " + str(confidence)
            labelSize, baseLine = cv2.getTextSize(label, cv2.FONT_HERSHEY_SIMPLEX, 0.5, 1)
            yLeftBottom = max(yLeftBottom, labelSize[1])
            cv2.rectangle(frame, (xLeftBottom, yLeftBottom - labelSize[1]),
                                 (xLeftBottom + labelSize[0], yLeftBottom + baseLine),
                                 (255, 255, 255), cv2.FILLED)
            cv2.putText(frame, label, (xLeftBottom, yLeftBottom),
                        cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 0, 0))
# Display
cv2.namedWindow("frame", cv2.WINDOW_NORMAL)
cv2.imshow("frame", frame)
if cv2.waitKey(1) >= 0: break
```

More samples at:
https://github.com/opencv/opencv/tree/master/samples/dnn

Thanks

Backups

OpenCL acceleration

- Auto-tuning

  - For each convolution “key”, generate a set of kernel configurations

  - Compile kernel for each kernel configuration, run kernel, get running time

  - Choose the best kernel configuration and store it on disk or memory

```
input_blob_shape: (0, 3, 300, 300)
output_channel: 64
filter_size: (3, 3)
stide_size: (2,2)
dilation_size: (1,1)
padding_size: (1, 1)
group: 1
has_bias: 1
activation_type: 0
eltwise: 1
half_float: 1
eu: 72
```

```
a set of kernel_config
(tile_h,tile_w,simd_size,kernel_type):
(2, 32, 8, 2),
(1, 32, 16, 2),
(4, 4, 8, 5),
(4, 4, 16, 5)
....
```

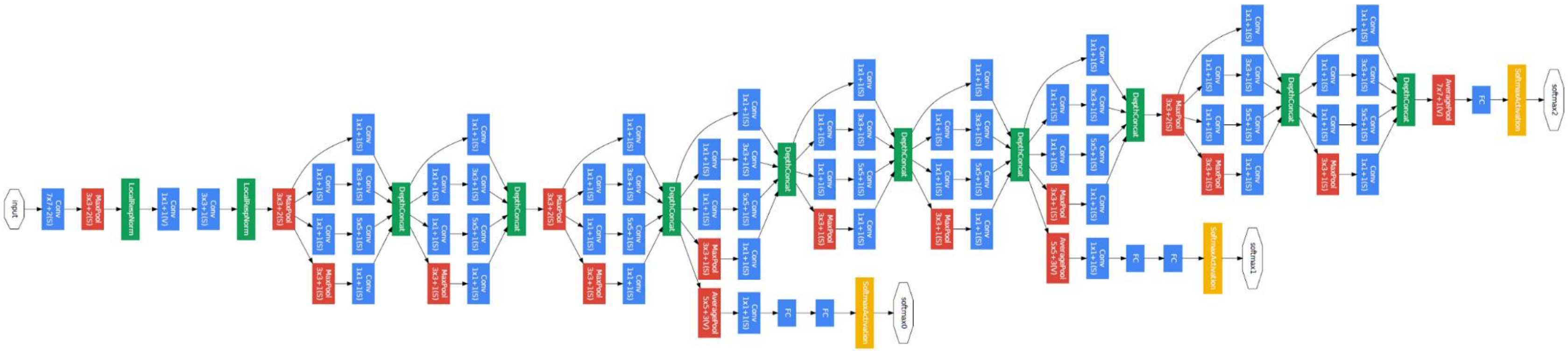
```
Best kernel config:
(1, 32, 16, 2)
```

A convolution “key” is
a combination of all convolution
parameters and GPU’s execution
unit number.

A kernel_config is a combination
of tile size, simd size and kernel
type

Key concepts of Deep Neural Networks (DNN)

- A sample : GoogLeNet-V1



21 convolution layers + FC layer