LeNet-5 using DLR

- running model and profiling -

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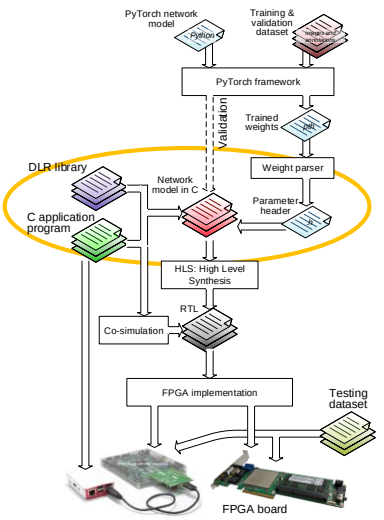
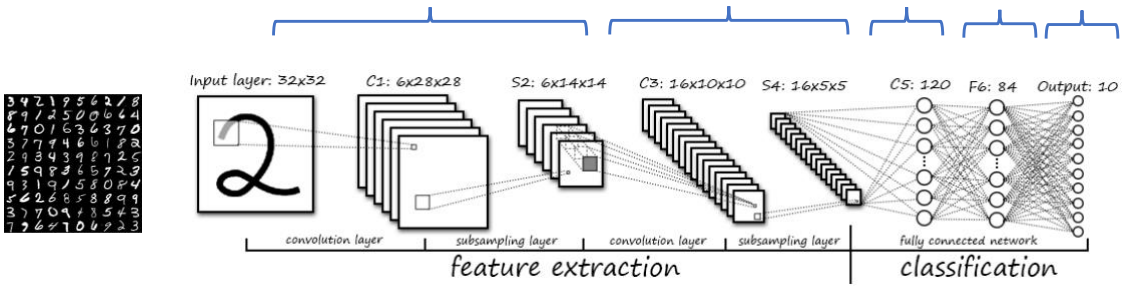
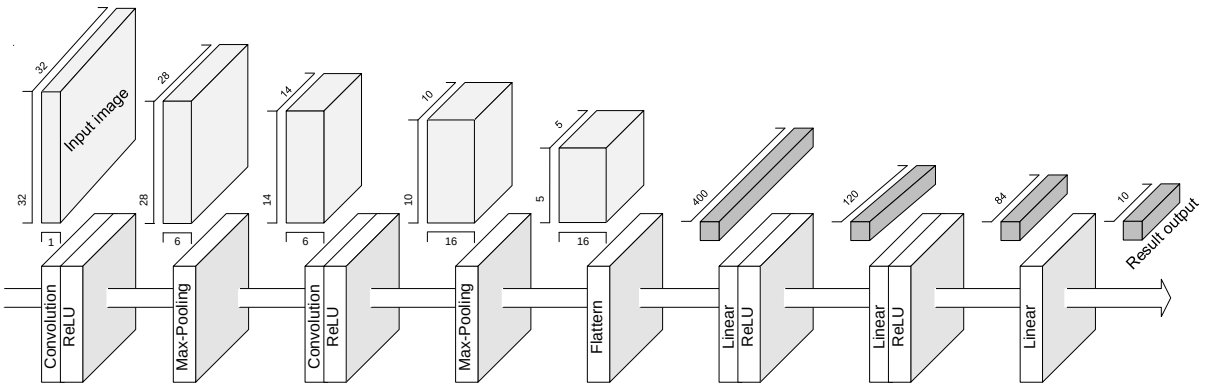


LeNet-5 for MNIST

- LeNet is one of the popular convolutional networks, and works well on digit classification tasks.
  - 1024 (32x32) inputs of black and white ➔ converted to floating number 0.0 ~ 1.0
  - 10 outputs representing digit 0 to 9



LeNet-5 network

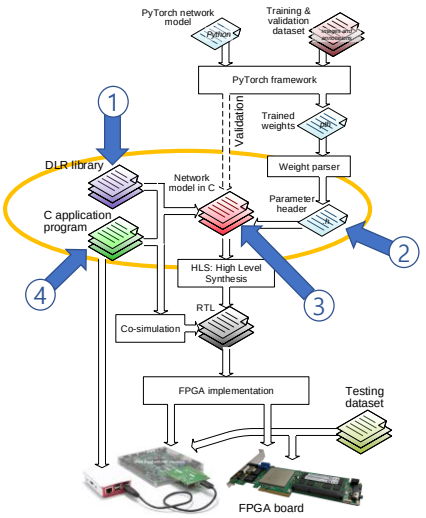


Modified LeNet-5 network

Layer		feature map (channel x W x H)		kernel size	stride	padding	Activation	Parameters (bias+weight)	Feature map
input	image	1	32x32	.	.	.	.	.	1,024
1	CONV	6	28x28	5x5	1	0	ReLU	6+150	4,704
2	MaxPOOL	6	14x14	2x2	2	0	.	0	1,176
3	CONV	16	10x10	5x5	1	0	ReLU	16+2,400	1,600
4	MaxPOOL	16	5x5	2x2	2	0	.	0	400
5	FC	.	120	.			ReLU	120+48,000	120
6	FC	.	84	.	.	.	ReLU	84+10,080	84
7	FC	.	10	.	.	.	softmax	10+840	10
								61,706	9,118

 # bias = # channel
 # weight for convolution= # in_channel x # out_channel x # kernel_size
 # feature map = # channel x # in_feature_map
 # weight for FC = # in_feature x # out_feature

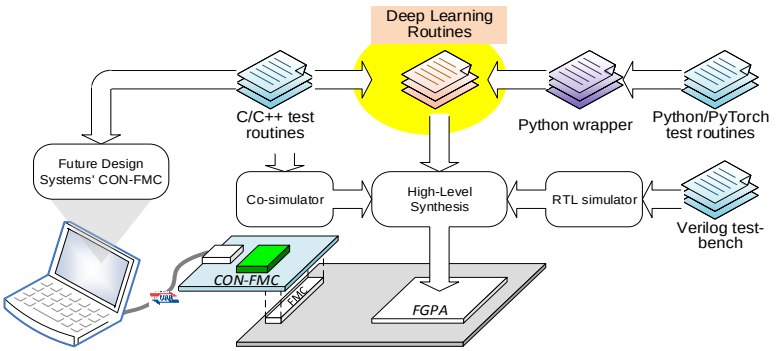
What are required



- (1) Deep Learning Routines
- (2) LeNet-5 trained parameters (weights)
- (3) LeNet-5 model in C/C++
- (4) Program to run LeNet-5 model

What is DLR

- 'DLR (Deep Learning Routines)' as a part of DPU (Deep Learning Processing Unit) is a collection of high-level synthesizable C/C++ routines for deep learning inference network.
  - https://github.com/github-fds/Deep_Learning_Routines



How to prepare DLR library

- Get a clone
  - $ git clone https://github.com/github-fds/Deep_Learning_Routines.git
- Go to 'src' directory
  - $ cd Deep_Learning_Routines/v1.3/src
- Compile and install (mind '--std=c++11')
  - $ make
  - $ make install
- See 'include' and 'lib' directories
  - $ cd ..
  - $ ls include lib

How to prepare and run the project

- Get a clone
  - $ git clone https://github.com/adki/DLR_Projects.git
- Go to ‘LeNet-5/LeNet-5.dlr/native.cpp’ directory
  - $ cd DLR_Projects/LeNet-5/LeNet-5.dlr/native.cpp
- Compile and install
  - (do not forget to set ‘DLR_HOME’ macro in ‘Makefile’)
  - $ make
  - $ make run

Where the trained parameter resides.

```
LeNet-5
  |-- LeNet-5.dlr
  |     +-- native.cpp
  |           +-- src
  |-- LeNet-5.dlr.fpga
  |   |-- hw
  |   |  |-- hls
  |   |  |    +-- tcl.float
  |   |  |-- impl
  |   |  |     +-- vivado.zed.confmc.float
  |   |  |           +-- xdc
  |   |  +-- iplib
  |   |        +-- bfm_axi
  |   +-- sw.native
  |         +-- lenet.confmc
  |               +-- src
  |-- LeNet-5.pytorch
  |   |-- samples
  |   +-- src
  +-- LeNet-5.pytorch.dlr
        +-- src
```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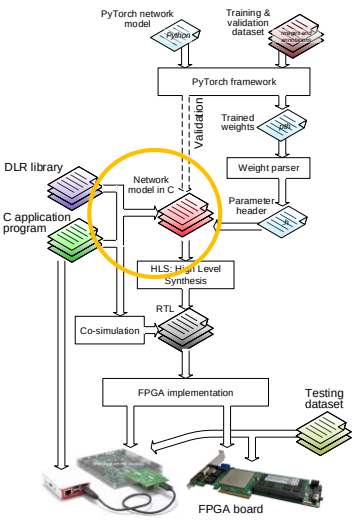
```
LeNet-5
  |-- LeNet-5.dlr
  |     \- native.cpp
  |
  |-- LeNet-5.dlr.fpga
  |
  |-- LeNet-5.pytorch
  |
  +-- LeNet-5.pytorch.dlr
```



lenet5.cpp

```
#include "dlr.hpp"
#include "lenet5_params.h"  // come from LeNet-5.pytorch

void lenet5(        DTYPE classes[10]
            , const DTYPE image  [32][32]
            #if !defined(__SYNTHESIS__)
            , const int rigor
            , const int verbose
            #endif
            )
{
          DTYPE      c1_out_data[6][28][28];
    const DTYPE    (*c1_in_data)[32][32]=(DTYPE (*)[32][32])image; // [1][32][32]
    const DTYPE    (*c1_kernel)[1][5][5]=(DTYPE (*)[1][5][5])conv1_weight; // [6][1][5][5]
    const DTYPE    (*c1_bias)=conv1_bias; // [6]
    const uint16_t  c1_out_size=28;
    const uint16_t  c1_in_size=32;
    const uint8_t   c1_kernel_size=5;
    const uint16_t  c1_bias_size=6;
    const uint16_t  c1_in_channel=1;
    const uint16_t  c1_out_channel=6;
    const uint8_t   c1_stride=1;
    const uint8_t   c1_padding=0;
```

```
Convolution2d<DTYPE> (
        (DTYPE *)c1_out_data
      , (DTYPE *)c1_in_data
      , (DTYPE *)c1_kernel
      , (DTYPE *)c1_bias
      ,          c1_out_size
      ,          c1_in_size
      ,          c1_kernel_size
      ,          c1_bias_size
      ,          c1_in_channel
      ,          c1_out_channel
      ,          c1_stride
      ,          c1_padding
      #if !defined(__SYNTHESIS__)
      ,          rigor
      ,          verbose
      #endif
);
```


main.cpp

```
int main( int argc, char* argv[]) {
    int num_images = arg_parser(argc, argv);

    int idx;
    for (idx=0; idx<num_images; idx++) {
        float classes[NUM_CLASSES];
        float image[IMAGE_HEIGHT][IMAGE_WIDTH];
        get_image_data( image_files[idx], (float *)image, 0, 2);
        lenet5( classes
              , image
              #if !defined(__SYNTHESIS__)
              , rigor
              , verbose
              #endif
              );
        float classes_softmax[NUM_CLASSES];
        softmax(classes_softmax, classes);
        printf("[%s]₩n", image_files[idx]);
        int idy;
        for (idy=0; idy<NUM_CLASSES; idy++) {
            printf("₩t[%d]: %f:%8.3f₩n", idy, classes_softmax[idy], classes[idy]);
        }
    }

    return 0;
}
```

Compile and run

- For g++ 5.x, mind '--std=c++11'
  - $ make
  - $ make run
  - or
  - $ make run.all

```
adki@ando-pc: ~/work/projects/DPU/DLR_Projects.master/LeNet-5/...
File  Edit  View  Search  Terminal  Help
(base) [adki@ando-pc] make run
./lenet5 --rigor ../../LeNet-5.pytorch/samples/t_00_c4.png
[../../LeNet-5.pytorch/samples/t_00_c4.png]
        [0]: 0.000000: -13.836
        [1]: 0.000000: -14.100
        [2]: 0.000000:  -0.527
        [3]: 0.000000: -19.281
        [4]: 1.000000:  40.089
        [5]: 0.000000:  -2.063
        [6]: 0.000000:  -4.218
        [7]: 0.000000:   1.709
        [8]: 0.000000:  -1.059
        [9]: 0.000000:   3.265
(base) [adki@ando-pc]
```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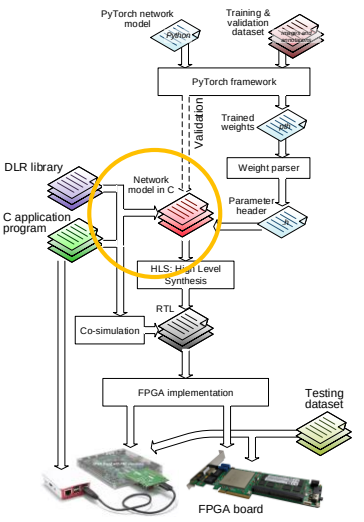


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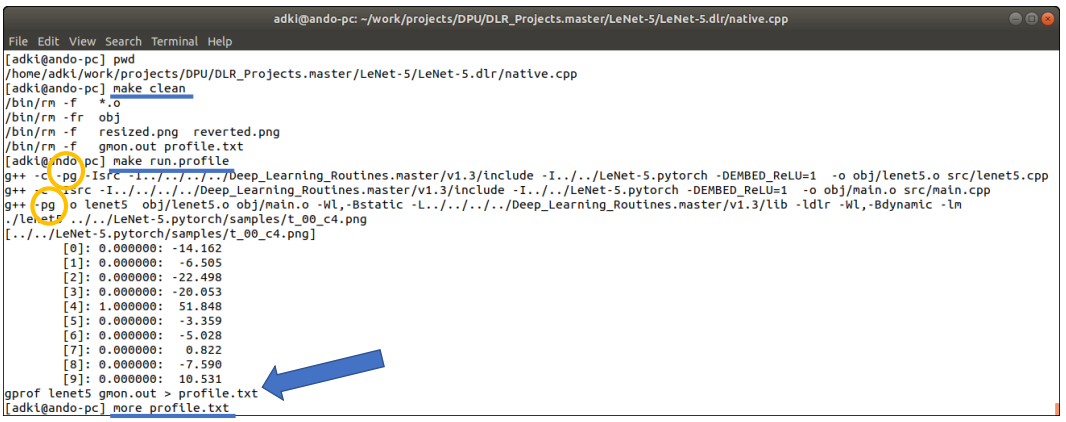
  |-- LeNet-5.dlr
  |     \- native.cpp
  |
  |-- LeNet-5.dlr.fpga
  |
  |-- LeNet-5.pytorch
  |
  +-- LeNet-5.pytorch.dlr
```

Compile and run

- For g++ 5.x, mind '--std=c++11'
  - $ make run.profile
- GNU GCC와 gprof 사용
  - 컴파일 단계에서 '-pg' 선택자 사용
  - 프로그램 수행 결과로 'gmon.out' 파일 생성
  - 'gprof' 프로그램으로 분석
- 1. compile and link using '-pg' option
- 2. run as normal
- 3. run using 'pgrof'
  - $ gprof lenet5 gmon.out > profile.txt

Compile and run



Profiling results