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**notes**

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This page describes how this website is setup.

## 1.1 Setup

1. Install the dependencies in `./docs/requirements.txt`.

```
sphinx==4.3.2
sphinx-autodoc-typehints==1.12.0
sphinx_rtd_theme==1.0.0
sphinxcontrib-bibtex==2.4.1
```

2. Use `sphinx-quickstart` to generate the skeleton. When it prompts:

```
Separate source and build directories(y/n)
```

Answer yes.

3. Edit `docs/source/conf.py` and add the following lines to it:

```
import sphinx_rtd_theme
extensions = [
    'sphinx.ext.autodoc',
    'sphinx.ext.autosummary',
    'sphinx.ext.githubpages',
    'sphinx.ext.mathjax',
    'sphinx.ext.napoleon',
    'sphinx.ext.todo',
    'sphinx.ext.viewcode',
    'sphinxcontrib.bibtex',
]

html_theme = 'sphinx_rtd_theme'

master_doc = 'index'
pygments_style = 'sphinx'
html_theme_path = [sphinx_rtd_theme.get_html_theme_path()]
smartquotes = False
html_show_sourcelink = True

html_context = {
```

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```
'display_github': True,
'github_user': 'csu-fangjun',
'github_repo': 'notes',
'github_version': 'master',
'conf_py_path': '/docs/source/',
}

html_theme_options = {
    'logo_only': False,
    'display_version': True,
    'prev_next_buttons_location': 'bottom',
    'style_external_links': True,
}
latex_engine = 'xelatex'
```

4. To generate the notes in pdf format, use `make latex`, which generates lots of `tex` files in `./build/latex`. Switch to `build/latex` and run `make`. Assume that you have installed the software to compile `tex` files. It will generate `notes.pdf`.

## 1.2 How to include code from a file

See <https://www.sphinx-doc.org/en/master/usage/restructuredtext/directives.html#directive-literalinclude>.

1. Show line number: `:linenos:`. By default, line number counts from 0. To add an offset, e.g., 10, to the line number, use `:lineno-start: 10`. Note: It still includes all the contents of the file.
2. To emphasize a line, specified lines, or specified line ranges, use: `:emphasize-lines: 10`, `:emphasize-lines: 10,12,14`, and `:emphasize-lines: 12,15-18`. Note: `emphasize` means to change the background color.
3. Set the language, e.g., `:language: python`.
4. Set the caption, e.g., `:caption: hello world`.
5. To include a function from the python file, use `:pyobject: my_func`.
6. To include specified lines, use `:lines:1,3,5-10,15-`. Note that if using this option, line number counts from 0. Use `:lineno-start: xx` to change the offset for display.

## 1.3 Link

See <https://sublime-and-sphinx-guide.readthedocs.io/en/latest/references.html> and <https://www.sphinx-doc.org/en/master/usage/restructuredtext/basics.html#hyperlinks>

### 1.3.1 hello

Here is a link to *hello*.

```
.. _Link to hello:
```

```
hello
```

```
-----
```

```
Here is a link to :ref:`Link to hello`.
```



This page describes commonly used git commands.

## 2.1 Commands

### 2.1.1 rev-parse

It is quite common to get the root directory of the repository with the command:

```
git rev-parse --show-toplevel
```

For instance, the above command executed in this repository prints something like as follows:

```
/xxx/notes
```

The following shows its usage in a Python script:

```
#!/usr/bin/env python3

import subprocess

d = (
    subprocess.check_output(["git", "rev-parse", "--show-toplevel"])
    .decode("ascii")
    .strip() # remove the trailing \n
)
print(d) # /path/to/notes
```

It can also be used in bash script:

```
root_dir=$(git rev-parse --show-toplevel)
echo "root_dir ${root_dir}"
```

help git-rev-parse outputs helpful information for git rev-parse. In particular, it explains the differences among HEAD~, HEAD~n, HEAD^, and HEAD^n. The following shows the help information about it:

```
<rev>^[<n>], e.g. HEAD^, v1.5.1^0
  A suffix ^ to a revision parameter means the first parent of that commit object. ^
  ↪<n> means the <n>th parent
```

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(i.e. `<rev>^` is equivalent to `<rev>^1`). As a special rule, `<rev>^0` means the commit itself and is used when `<rev>` is the object name of a tag object that refers to a commit object.

`<rev>~[<n>]`, e.g. `HEAD~`, `master~3`

A suffix `~` to a revision parameter means the first parent of that commit object. A suffix `~<n>` to a revision parameter means the commit object that is the `<n>`th generation ancestor of the named commit object, following only the first parents. I.e. `<rev>~3` is equivalent to `<rev>^^^` which is equivalent to `<rev>^1^1^1`. See below for an illustration of the usage of this form.



$A = A^0$   
 $B = A^1 = A^1_1 = A_{~1}$   
 $C = A^2$   
 $D = A^{11} = A^{1^1_1} = A_{~2}$   
 $E = B^2 = A^{12}$   
 $F = B^3 = A^{13}$   
 $G = A^{111} = A^{1^1_1^1} = A_{~3}$   
 $H = D^2 = B^{12} = A^{112} = A_{~2}^2$   
 $I = F^1 = B^{13} = A^{113}$   
 $J = F^2 = B^{132} = A^{1132}$



## 3.1 Installation

### 3.1.1 macos

Refer to <https://docs.docker.com/desktop/mac/install/>.



## **4.1 TikZ**

### **4.1.1 Basics**



This page describes commonly used git commands.

## 5.1 Decoding

```
CompactLattice compact_lat;  
decoder.GetLattice(true, &compact_lat);  
  
CompactLattice compact_best_path;  
CompactLatticeShortestPath(compact_lat, &compact_best_path);  
  
Lattice best_path;  
ConvertLattice(compact_best_path, best_path);  
  
std::vector<int32_t> tokens;  
std::vector<int32_t> words;  
LatticeWeight weight;  
GetLinearSymbolSequence(best_path, &tokens, &words, &weight);
```

- `decoder/simple-decoder.{h,cc}`



## 6.1 sort

Sort files in the folder `t`. The filename has the pattern `xxx.n.txt`, where `n` is some numerical value. Also, exclude `xxx.100.txt`.

```
find ./t -name "xxx*.txt" ! -name "xxx.100.txt" -print0 | sort -z -t. -k2 -n | xargs -r0
```

## 6.2 echo

Generate a binary file:

```
echo -n -e '\x30\x31\x32' > a.bin  
hexdump a.bin
```

## 6.3 ffmeg

```
ffprobe xxx.opus
```

### 6.3.1 Convert format

- opus to wav

```
ffmpeg -i input.opus output.wav  
  
ffmpeg -i input.opus -acodec pcm_s16le -ac 1 -ar 16000 output.wav
```

- Extract part of a file

```
# extract 30 seconds starting at offset 1 minute  
ffmpeg -i input.opus -ss 60 -t 30 output.wav  
# or use HH:MM:SS format  
ffmpeg -i input.opus -ss 0:01:00 -t 0:00:30 output.wav
```

### 6.3.2 References

See <https://gist.github.com/whizkydee/804d7e290f46c73f55a84db8a8936d74>



## 7.1 Installation

### 7.1.1 CUDA 10.1.243

```
./cuda_10.1.243_418.87.00_linux.run --silent --toolkit --installpath=/ceph-data4/fangjun/  
↪software/cuda-10.1.243 --no-opengl-libs --no-drm --no-man-page  
  
# Install cuDNN  
cd /ceph-data4/fangjun/software/cuda-10.1.243  
tar xvf /ceph-sh0/fangjun/cudnn/cudnn-10.1-linux-x64-v8.0.4.30.tgz --strip-components=1
```

```
#!/usr/bin/env bash  
  
export CUDA_HOME=/ceph-data4/fangjun/software/cuda-10.1.243  
export PATH=$CUDA_HOME/bin:$PATH  
export LD_LIBRARY_PATH=$CUDA_HOME/lib64:$LD_LIBRARY_PATH  
  
# See /ceph-fj/fangjun/py38/lib/python3.8/site-packages/torch/share/cmake/Caffe2/Modules_  
↪CUDA_fix/upstream/FindCUDA.cmake  
export CUDA_TOOLKIT_ROOT_DIR=$CUDA_HOME  
export CUDA_TOOLKIT_ROOT=$CUDA_HOME  
export CUDA_BIN_PATH=$CUDA_HOME  
export CUDA_PATH=$CUDA_HOME  
export CUDA_INC_PATH=$CUDA_HOME/targets/x86_64-linux
```

### 7.1.2 CUDA 10.2.89

```
./cuda_10.2.89_440.33.01_linux.run --silent --toolkit --installpath=/ceph-data4/fangjun/  
↪software/cuda-10.2.89 --no-opengl-libs --no-drm --no-man-page  
# Install cuDNN  
wget https://huggingface.co/csukuangfj/cudnn/resolve/main/cudnn-10.2-linux-x64-v8.0.2.39.  
↪tgz  
tar xvf cudnn-10.2-linux-x64-v8.0.2.39.tgz --strip-components=1 -C /ceph-data4/fangjun/  
↪software/cuda-10.2.89
```

```
#!/usr/bin/env bash

export CUDA_HOME=/ceph-sh1/fangjun/software/cuda-10.2.89
export PATH=$CUDA_HOME/bin:$PATH
export LD_LIBRARY_PATH=$CUDA_HOME/lib64:$LD_LIBRARY_PATH
export LD_LIBRARY_PATH=$CUDA_HOME/lib:$LD_LIBRARY_PATH

# See /ceph-fj/fangjun/py38/lib/python3.8/site-packages/torch/share/cmake/Caffe2/Modules_
↳ CUDA_fix/upstream/FindCUDA.cmake
export CUDA_TOOLKIT_ROOT_DIR=$CUDA_HOME
export CUDA_TOOLKIT_ROOT=$CUDA_HOME
export CUDA_BIN_PATH=$CUDA_HOME
export CUDA_PATH=$CUDA_HOME
export CUDA_INC_PATH=$CUDA_HOME/targets/x86_64-linux
export CFLAGS=-I$CUDA_HOME/targets/x86_64-linux/include
```

### 7.1.3 CUDA 11.0.3

```
./cuda_11.0.3_450.51.06_linux.run --silent --toolkit --installpath=/ceph-data4/fangjun/
↳ software/cuda-11.0.3 --no-opengl-libs --no-drm --no-man-page

# Install cuDNN
cd /ceph-data4/fangjun/software/cuda-11.0.3
tar xvf /ceph-sh0/fangjun/cudnn/cudnn-11.0-linux-x64-v8.0.4.30.tgz --strip-components=1
```

### 7.1.4 CUDA 11.3.1

```
./cuda_11.3.1_465.19.01_linux.run --silent --toolkit --installpath=/ceph-data4/fangjun/
↳ software/cuda-11.3.1 --no-opengl-libs --no-drm --no-man-page
cd /ceph-data4/fangjun/software/cuda-11.3.1
tar xvf /ceph-sh0/fangjun/cudnn/cudnn-11.3-linux-x64-v8.2.1.32.tgz --strip-components=1
```

### 7.1.5 CUDA 11.5.2

```
./cuda_11.5.2_495.29.05_linux.run --silent --toolkit --installpath=/ceph-data4/fangjun/  
↳ software/cuda-11.5.2 --no-opengl-libs --no-drm --no-man-page  
cd /ceph-data4/fangjun/software/cuda-11.5.2  
tar xvf /ceph-sh0/fangjun/cudnn/cudnn-linux-x86_64-8.3.2.44_cuda11.5-archive.tar.xz --  
↳ strip-components=1
```

### 7.1.6 CUDA 11.6.1

```
./cuda_11.6.1_510.47.03_linux.run --silent --toolkit --installpath=/ceph-data4/fangjun/  
↳ software/cuda-11.6.1 --no-opengl-libs --no-drm --no-man-page  
cd /ceph-data4/fangjun/software/cuda-11.6.1  
tar xvf /ceph-sh0/fangjun/cudnn/cudnn-11.3-linux-x64-v8.2.1.32.tgz --strip-components=1
```

### 7.1.7 CUDA 11.7.1

```
wget https://developer.download.nvidia.com/compute/cuda/11.7.1/local_installers/cuda_11.  
↳ 7.1_515.65.01_linux.run  
chmod +x cuda_11.7.1_515.65.01_linux.run  
./cuda_11.7.1_515.65.01_linux.run --silent --toolkit --installpath=/ceph-data4/fangjun/  
↳ software/cuda-11.7.1 --no-opengl-libs --no-drm --no-man-page  
cd /ceph-data4/fangjun/software/cuda-11.7.1
```



## 8.1 torch.load and torch.save

Listing 1: ./code/load-and-save.py

```
1  #!/usr/bin/env python3
2
3  import torch
4  import tempfile
5
6
7  def main():
8      a = torch.arange(3)
9      with tempfile.NamedTemporaryFile() as f:
10         torch.save(a, f)
11         f.seek(0)
12         b = torch.load(f)
13         assert torch.all(torch.eq(a, b)), (a, b)
14
15
16 if __name__ == "__main__":
17     main()
```

## 8.2 torch.gather

Listing 2: ./code/gather.py

```
1  #!/usr/bin/env python3
2
3  import torch
4
5
6  def main():
7      left_context = 0
8      N = 1
9      T = 1
10     H = 5 # time1
11     W = 2 * H - 1 + left_context # 2time1 - 1 + left_context
```

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```
12 a = torch.randn(N, T, H, W)
13 a = torch.arange(N * T * H * W).reshape(N, T, H, W).contiguous()
14
15 if True:
16     rows = torch.arange(start=H - 1, end=-1, step=-1).unsqueeze(-1)
17     cols = torch.arange(H + left_context)
18     indexes = rows + cols
19
20     indexes = torch.tile(indexes, (N * T, 1))
21 else:
22     rows = torch.arange(start=H - 1, end=-1, step=-1)
23     cols = torch.arange(H + left_context)
24     rows = torch.cat([rows] * (N * T)).unsqueeze(-1)
25     indexes = rows + cols
26
27 print(indexes.shape)
28
29 ta = a.reshape(-1, W)
30
31 b = torch.gather(ta, dim=1, index=indexes)
32 b = b.reshape(N, T, H, -1)
33
34 c = a.as_strided(
35     (N, T, H, H + left_context),
36     (T * H * W, H * W, W - 1, 1),
37     storage_offset=H - 1,
38 )
39 assert torch.equal(b, c), (b, c)
40
41
42 if __name__ == "__main__":
43     torch.manual_seed(20220727)
44     main()
```

## 8.3 DDP

### 8.3.1 Initialization

## 8.4 TorchScript

### 8.4.1 doxygen doc

See

## 8.4.2 Hello

See [https://pytorch.org/tutorials/beginner/Intro\\_to\\_TorchScript\\_tutorial.html](https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html).

### `torch.jit.script` as a decorator

Listing 3: `./code/1-ex.py`

```

1  @torch.jit.script
2  def adder(x: int):
3      return x + 1
4
5
6  def test_adder():
7      assert isinstance(adder, torch.jit.ScriptFunction)
8      print(adder.graph)
9      print("-" * 10)
10     print(adder.code)
11     adder.save("adder.pt")
12
13     my_adder = torch.jit.load("adder.pt")
14
15     assert isinstance(my_adder, torch.jit._script.RecursiveScriptModule)
16     assert isinstance(my_adder, torch.jit.ScriptModule)
17     assert not isinstance(my_adder, torch.jit.ScriptFunction)
18     print(my_adder(torch.tensor([3])))
19
20
21     """
22     graph(%x.1 : int):
23         %2 : int = prim::Constant[value=1]() # ./1-ex.py:8:15
24         %3 : int = aten::add(%x.1, %2) # ./1-ex.py:8:11
25         return (%3)
26
27     -----
28     def adder(x: int) -> int:
29         return torch.add(x, 1)
30
31     4
32     """

```

### `torch.jit.script` as a function

Listing 4: `./code/2-ex.py`

```

1  def adder(x: int):
2      return x + 2
3
4
5  def test_adder():
6      adder_func = torch.jit.script(adder)

```

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```

7  assert isinstance(add_func, torch.jit.ScriptFunction)
8  print(add_func.graph)
9  print(add_func(3))
10
11
12  """
13  graph(%x.1 : int):
14      %2 : int = prim::Constant[value=2]() # ./2-ex.py:6:15
15      %3 : int = aten::add(%x.1, %2) # ./2-ex.py:6:11
16      return (%3)
17
18  5
19  """

```

## torchscript a module

Listing 5: ./code/3-ex.py

```

1  class MyModel(torch.nn.Module):
2      def __init__(self):
3          super().__init__()
4          self.p = torch.nn.Parameter(torch.tensor([2.0]))
5
6      def forward(self, x: torch.Tensor):
7          return self.p * x
8
9
10 def test_my_model():
11     model = MyModel()
12     scripted_model = torch.jit.script(model)
13     print(scripted_model.graph)
14     print("-" * 10)
15     print(scripted_model.code)
16     print(scripted_model(torch.tensor([10])))
17
18
19 """
20 graph(%self : __torch__.MyModel,
21     %x.1 : Tensor):
22     %p : Tensor = prim::GetAttr[name="p"](%self)
23     %4 : Tensor = aten::mul(%p, %x.1) # ./3-ex.py:12:15
24     return (%4)
25
26 -----
27 def forward(self,
28     x: Tensor) -> Tensor:
29     p = self.p
30     return torch.mul(p, x)
31 """

```



## trace a module

Listing 6: ./code/trace/ex0.py

```

1  #!/usr/bin/env python3
2
3  import torch
4
5  import torch.nn as nn
6  from typing import List
7
8
9  class Foo(nn.Module):
10     def __init__(self):
11         super().__init__()
12         self.relu = nn.ReLU()
13
14     def forward(self, x):
15         return self.relu(x)
16
17
18 def test_foo():
19     f = Foo()
20     m = torch.jit.trace(f, torch.rand(2, 3))
21
22     print(m(torch.rand(2)))
23     print(m(torch.rand(2, 3, 4)))
24     # Note: The input shape is dynamic, not fixed.
25
26
27 def simple(x: List[torch.Tensor], y: torch.Tensor):
28     x = x[0].item()
29     if x > 2:
30         return y + x + 1
31     elif x < 1:
32         return y
33     else:
34         return y + x
35
36
37 def test_simple():
38     f0 = torch.jit.trace(simple, ([torch.tensor([0])], torch.rand(2, 3)))
39     # print(dir(f0))
40     """
41     ['__call__', '__class__', '__delattr__', '__dict__', '__dir__', '__doc__',
42     '__eq__', '__format__', '__ge__', '__getattr__', '__gt__', '__hash__',
43     '__init__', '__init_subclass__', '__le__', '__lt__', '__module__', '__ne__',
44     '__new__', '__reduce__', '__reduce_ex__', '__repr__', '__setattr__',
45     '__sizeof__', '__str__', '__subclasshook__', '_debug_flush_compilation_cache',
46     'code', 'get_debug_state', 'graph', 'graph_for', 'inlined_graph', 'name',
47     'qualified_name', 'save', 'save_to_buffer', 'schema']
48     """
49     # print(f0.schema) # simple(Tensor[] x, Tensor y) -> (Tensor)

```

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```

50     # print(f0.code)
51     """
52     def simple(x: List[Tensor],
53               y: Tensor) -> Tensor:
54         return y
55     """
56     # print(f0.graph)
57     """
58     graph(%x : Tensor[],
59           %y : Float(2, 3, strides=[3, 1], requires_grad=0, device=cpu)):
60         return (%y)
61     """
62     # print(f0.inlined_graph) # same as the above one
63     # print(f0.name) # simple
64     print(f0.qualified_name) # __torch__.simple
65
66
67 def main():
68     # test_foo()
69     test_simple()
70
71
72 if __name__ == "__main__":
73     main()

```

## Export and ignore methods

1. Use `@torch.jit.export` decorator to export a method.
2. Use `torch.jit.export` function call to export a method.
3. Use `@torch.jit.ignore` decorator to ignore a method.
4. Use `torch.jit.ignore` function call to ignore a method.
5. Use `@torch.jit.unused` or `torch.jit.unused` to ignore a method.

See [Load in C++](#) to load the saved file.

Listing 7: `./code/4-ex.py`

```

1 class MyModel(torch.nn.Module):
2     def __init__(self):
3         super().__init__()
4         self.p = torch.nn.Parameter(torch.tensor([2.0]))
5
6     def foo(self, x: torch.Tensor):
7         return x + 3
8
9     def bar(self, x: torch.Tensor):
10         return self.foo(x)
11
12     def baz(self, x: torch.Tensor):

```

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```

13     return self.p - x
14
15     @torch.jit.export
16     def baz(self, x: torch.Tensor):
17         return self.p + x + 2
18
19     def forward(self, x: torch.Tensor):
20         return self.p * x
21
22
23 def test_my_model():
24     MyModel.foo = torch.jit.export(MyModel.foo) # manually export
25
26     # Note: forward is exported by default. We ignore it here manually
27     MyModel.forward = torch.jit.ignore(MyModel.forward)
28
29     model = MyModel()
30     scripted_model = torch.jit.script(model)
31     assert hasattr(scripted_model, "foo")
32     assert hasattr(scripted_model, "baz")
33     assert hasattr(scripted_model, "foobar") # because it is called by `foo`
34     assert not hasattr(scripted_model, "bar")
35
36     scripted_model.save("foo.pt")
37
38     m = torch.jit.load("foo.pt")
39     print(m.foo(torch.tensor([1])))
40     print(m.baz(torch.tensor([1])))
41
42
43 """
44 graph(%self : __torch__.MyModel,
45       %x.1 : Tensor):
46     %p : Tensor = prim::GetAttr[name="p"](%self)
47     %4 : Tensor = aten::mul(%p, %x.1) # ./3-ex.py:12:15
48     return (%4)
49
50 -----
51 def forward(self,
52             x: Tensor) -> Tensor:
53     p = self.p
54     return torch.mul(p, x)
55 """

```

### 8.4.3 Load in C++

See [https://pytorch.org/tutorials/advanced/cpp\\_export.html](https://pytorch.org/tutorials/advanced/cpp_export.html).

Load the saved `foo.pt` in C++ from *Export and ignore methods*.

Listing 8: `./code/load-in-cpp/Makefile`

```

1  USE_CXX11_ABI := $(shell python3 -c 'import torch; print(int(torch.compiled_with_cxx11_
   ↳abi()))')
2  TORCH_INSTALL_DIR := $(shell python3 -c 'import os; import torch; print(os.path.
   ↳dirname(torch.__file__))')
3
4  $(info USE_CXX11_ABI $(USE_CXX11_ABI))
5  $(info TORCH_INSTALL_DIR $(TORCH_INSTALL_DIR))
6
7  CXXFLAGS := -I$(TORCH_INSTALL_DIR)/include
8  CXXFLAGS += -I$(TORCH_INSTALL_DIR)/include/torch/csrc/api/include
9  CXXFLAGS += -I$(TORCH_INSTALL_DIR)/include/TH
10 CXXFLAGS += -I$(TORCH_INSTALL_DIR)/include/THC
11 CXXFLAGS += -std=c++14
12 CXXFLAGS += -D_GLIBCXX_USE_CXX11_ABI=$(USE_CXX11_ABI)
13
14 CXXFLAGS += -Wno-unknown-pragmas # disable omp warnings
15
16 LDFLAGS := -L$(TORCH_INSTALL_DIR)/lib
17 LDFLAGS += -lc10 -ltorch -ltorch_cpu
18 # LDFLAGS += -lc10 -ltorch
19 LDFLAGS += -Wl,-rpath,$(TORCH_INSTALL_DIR)/lib
20
21 HAS_CUDA := $(shell python3 -c 'import torch; print("yes" if torch.cuda.is_available()
   ↳else "no")')
22 HAS_CUDA := yes
23 $(info has cuda $(HAS_CUDA))
24
25 ifeq ($(HAS_CUDA),yes)
26 CUDA_HOME := $(shell which nvcc | xargs dirname | xargs dirname)
27 CXXFLAGS += -I$(CUDA_HOME)/include
28 LDFLAGS += -L$(CUDA_HOME)/lib64
29 LDFLAGS += -lcudart -lc10_cuda -ltorch_cuda
30 LDFLAGS += -Wl,-rpath,$(CUDA_HOME)/lib64
31 endif
32
33 .PHONY: clean
34
35 main: main.o
36     $(CXX) -o $@ $< $(LDFLAGS)
37
38 main.o: main.cc
39     $(CXX) $(CXXFLAGS) -c -o $@ $<
40
41 clean:
42     $(RM) main.o main

```

---

**Note:** `torch::jit::script::Module` is deprecated, use `torch::jit::Module` instead.

---

Listing 9: `./code/load-in-cpp/main.cc`

```

1  #include "torch/script.h"
2
3  int main() {
4      // see torch/csrc/jit/module.h
5      torch::jit::Module m = torch::jit::load("../foo.pt");
6      std::cout << "is training: " << m.is_training() << "\n";
7      m.eval();
8      std::cout << "after m.eval(): is training: " << m.is_training() << "\n";
9      torch::Tensor x = torch::tensor({1, 2, 3}, torch::kFloat);
10     torch::Tensor y = m.run_method("baz", x).toTensor();
11     std::cout << y << "\n";
12
13     return 0;
14 }

```

The output of `make` is:

```

USE_CXX11_ABI 0
TORCH_INSTALL_DIR /ceph-fj/fangjun/software/py38/lib/python3.8/site-packages/torch
has cuda yes
g++ -I/ceph-fj/fangjun/software/py38/lib/python3.8/site-packages/torch/include \
    -I/ceph-fj/fangjun/software/py38/lib/python3.8/site-packages/torch/include/torch/
↪csrc/api/include \
    -I/ceph-fj/fangjun/software/py38/lib/python3.8/site-packages/torch/include/TH \
    -I/ceph-fj/fangjun/software/py38/lib/python3.8/site-packages/torch/include/THC \
    -std=c++14 \
    -D_GLIBCXX_USE_CXX11_ABI=0 \
    -Wno-unknown-pragmas \
    -I/ceph-sh1/fangjun/software/cuda-10.2.89/include \
    -c -o main.o main.cc
g++ -o main main.o \
    -L/ceph-fj/fangjun/software/py38/lib/python3.8/site-packages/torch/lib \
    -lc10 -ltorch -ltorch_cpu \
    -Wl,-rpath,/ceph-fj/fangjun/software/py38/lib/python3.8/site-packages/torch/lib \
    -L/ceph-sh1/fangjun/software/cuda-10.2.89/lib64 \
    -lcudart -lc10_cuda -ltorch_cuda \
    -Wl,-rpath,/ceph-sh1/fangjun/software/cuda-10.2.89/lib64

```

The output of `./main` is:

```

is training: 1
after m.eval(): is training: 0
5
6
7
[ CPUFloatType{3} ]

```

### 8.4.4 ArrayRef

See `c10/utils/ArrayRef.h`.

**Caution:** `IntArrayRef` is an alias to `ArrayRef<int64_t>`.

`ArrayRef<T>` contains only two members: A const data pointer and a size. It is trivially copyable and assignable.

It has similar methods like `std::vector`. It also has two methods to get the front and back: `front()` and `back()`; both return a const reference.

Its method `vec()` converts itself to a `std::vector` by **copying** the underlying data.

#### Constructors

#### Data members

Listing 10: `./code/array_ref/main.cc` (Check size)

```
1 struct Foo {  
2     const int32_t *p;  
3     size_t len;  
4 };  
5  
6 static void TestSize() {  
7     // Note: The data pointer in ArrayRef is const!  
8     static_assert(sizeof(torch::ArrayRef<int32_t>) == sizeof(Foo), "");  
9 }
```

#### Default constructed

Listing 11: ./code/array\_ref/main.cc (Default constructor)

```
1 static void TestDefaultConstructor() {
2     torch::ArrayRef<int32_t> a;
3     TORCH_CHECK(a.data() == nullptr);
4     TORCH_CHECK(a.size() == 0);
5     TORCH_CHECK(a.empty() == true);
6
7     TORCH_CHECK(a.begin() == nullptr);
8     TORCH_CHECK(a.end() == nullptr);
9 }
```

### From a single element

Listing 12: ./code/array\_ref/main.cc (From a single element)

```
1 static void TestFromSingleElement() {
2     int32_t a = 10;
3     torch::ArrayRef<int32_t> b(a);
4     TORCH_CHECK(b[0] == a);
5     TORCH_CHECK(b.data() == &a);
6     TORCH_CHECK(b.size() == 1);
7 }
```

### From an initializer list

Listing 13: ./code/array\_ref/main.cc (From an initializer list)

```
1 static void TestFromInitializerList() {
2     torch::ArrayRef<int32_t> a = {1, 2, 3};
3     TORCH_CHECK(a.size() == 3);
4     TORCH_CHECK(a[0] == 1);
5     TORCH_CHECK(a[1] == 2);
6     TORCH_CHECK(a[2] == 3);
7 }
```

### Other types of constructors

- From two pointers: begin and end
- From a pointer and a length
- From a *std::vector*
- From a container that has `data()` and `size()` methods
- From a C array
- From a *std::array*

## 8.4.5 ScalarType

See `c10/core/ScalarType.h` and <https://github.com/pytorch/pytorch/blob/master/torch/csrc/api/include/torch/types.h>.

ScalarType is an enum class, i.e., `enum class ScalarType : int8_t { ... }`.

### Members

It has the following members:

Listing 14: `./code/scalar-type/members.cc`

```

1  #define AT_FORALL_SCALAR_TYPES_WITH_COMPLEX_EXCEPT_COMPLEX_HALF(_) \
2      _(uint8_t, Byte) \
3      _(int8_t, Char) \
4      _(int16_t, Short) \
5      _(int, Int) \
6      _(int64_t, Long) \
7      _(at::Half, Half) \
8      _(float, Float) \
9      _(double, Double) \
10     _(c10::complex<float>, ComplexFloat) \
11     _(c10::complex<double>, ComplexDouble) \
12     _(bool, Bool) \
13     _(at::BFloat16, BFloat16)

```

### Some aliases

Listing 15: `./code/scalar-type/main.cc` (alias)

```

1  static void TestAlias() {
2      static_assert(c10::ScalarType::Int == c10::kInt, "");
3      static_assert(c10::ScalarType::Byte == c10::kByte, "");
4  }

```

Listing 16: `./code/scalar-type/alias.cc`

```

1  // See torch/csrc/api/include/torch/types.h
2  using Dtype = at::ScalarType;
3
4  /// Fixed width dtypes.
5  constexpr auto kUInt8 = at::kByte;
6  constexpr auto kInt8 = at::kChar;
7  constexpr auto kInt16 = at::kShort;
8  constexpr auto kInt32 = at::kInt;
9  constexpr auto kInt64 = at::kLong;
10 constexpr auto kFloat16 = at::kHalf;
11 constexpr auto kFloat32 = at::kFloat;
12 constexpr auto kFloat64 = at::kDouble;
13
14 /// Rust-style short dtypes.
15 constexpr auto kU8 = kUInt8;

```

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```

16 constexpr auto kI8 = kInt8;
17 constexpr auto kI16 = kInt16;
18 constexpr auto kI32 = kInt32;
19 constexpr auto kI64 = kInt64;
20 constexpr auto kF16 = kFloat16;
21 constexpr auto kF32 = kFloat32;
22 constexpr auto kF64 = kFloat64;

```

## ScalarType to CPP type

Listing 17: ./code/scalar-type/main.cc

```

1 static void TestScalarTypeToCppType() {
2     static_assert(
3         std::is_same<
4             int32_t, //
5             c10::impl::ScalarTypeToCppType<c10::ScalarType::Int>::type>::value,
6         "");
7 }

```

## CPP type to ScalarType

Listing 18: ./code/scalar-type/main.cc

```

1 static void TestCppTypeToScalarType() {
2     static_assert(
3         c10::CppTypeToScalarType<float>::value == c10::ScalarType::Float, "");
4 }

```

**Note:** It is `c10::impl::ScalarTypeToCppType`, but it is `c10::CppTypeToScalarType`.

## 8.4.6 TypeMeta

See

- <https://github.com/pytorch/pytorch/blob/master/c10/util/typeid.h>
- <https://github.com/pytorch/pytorch/blob/master/c10/core/ScalarTypeToTypeMeta.h>

`struct TypeMeta` contains only a single `int16_t` data member:

Listing 19: ./code/type-meta/main.cc (Check size)

```

1 static void TestSize() {
2     static_assert(sizeof(caffe2::TypeMeta) == sizeof(int16_t), "");
3 }

```

## Constructors

Listing 20: ./code/type-meta/main.cc (Make)

```

1 static void TestConstructor() {
2     caffe2::TypeMeta t = caffe2::TypeMeta::Make<int32_t>();
3     TORCH_CHECK(t.Match<int32_t>());
4
5     TORCH_CHECK(t.isScalarType());
6
7     TORCH_CHECK(t.isScalarType(torch::kInt));
8     TORCH_CHECK(t.isScalarType(torch::kFloat) == false);
9
10    TORCH_CHECK(t.name() == "int");
11 }

```

## Operations with ScalarType

Listing 21: ./code/type-meta/main.cc (Operations with ScalarType)

```

1 static void TestFromScalarType() {
2     caffe2::TypeMeta t = caffe2::TypeMeta::fromScalarType(torch::kDouble);
3
4     TORCH_CHECK(t.isScalarType(torch::kDouble));
5     TORCH_CHECK(t.name() == "double");
6
7     TORCH_CHECK(t.toScalarType() == torch::kDouble);
8     TORCH_CHECK(t == torch::kDouble);
9     TORCH_CHECK(t != torch::kFloat);
10    TORCH_CHECK(torch::kInt != t);

```

### 8.4.7 torch::Device

See

- <https://github.com/pytorch/pytorch/blob/master/c10/core/DeviceType.h>
- <https://github.com/pytorch/pytorch/blob/master/c10/core/Device.h>

#### DeviceType

`torch::DeviceType` is defined as enum class `Device: int8_t {...}`. The most commonly used types are `torch::DeviceType::CPU` and `torch::DeviceType::CUDA`, which are aliased to `torch::kCPU` and `torch::kCUDA`.

Listing 22: ./code/device/main.cc

```

1 void TestDeviceType() {
2     torch::DeviceType d = torch::kCPU;
3     std::ostringstream os;
4     os << d;

```

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```

5 TORCH_CHECK(os.str() == "cpu");
6
7 TORCH_CHECK(DeviceTypeName(d /*,lower_case=false*/ ) == "CPU");
8 TORCH_CHECK(DeviceTypeName(d, /*lower_case*/ true) == "cpu");

```

## Device

A `torch::Device` class has two members: a `torch::DeviceType` and an `int8_t index`.

Listing 23: `./code/device/main.cc` (Constructors)

```

1 void TestDeviceConstructorCPU() {
2     torch::Device d(torch::kCPU);
3     TORCH_CHECK(d.is_cpu() == true);
4     TORCH_CHECK(d.is_cuda() == false);
5     TORCH_CHECK(d.type() == torch::kCPU);
6     TORCH_CHECK(d.has_index() == false);
7     TORCH_CHECK(d.index() == -1);
8     TORCH_CHECK(d.str() == "cpu");
9 }
10
11 void TestDeviceConstructorCUDA() {
12     torch::Device d(torch::kCUDA, 3);
13     TORCH_CHECK(d.is_cpu() == false);
14     TORCH_CHECK(d.is_cuda() == true);
15     TORCH_CHECK(d.type() == torch::kCUDA);
16     TORCH_CHECK(d.has_index() == true);
17     TORCH_CHECK(d.index() == 3);
18     TORCH_CHECK(d.str() == "cuda:3");
19
20     d.set_index(2);
21     TORCH_CHECK(d.index() == 2);
22     TORCH_CHECK(d.str() == "cuda:2");
23
24     d = torch::Device("cpu");
25     TORCH_CHECK(d.is_cpu() == true);
26
27     d = torch::Device("CPU");
28     TORCH_CHECK(d.is_cpu() == true);
29
30     d = torch::Device("cuda:1");
31     TORCH_CHECK(d.is_cuda() == true);
32     TORCH_CHECK(d.index() == 1);
33
34     d = torch::Device("CUDA:1");
35     TORCH_CHECK(d.is_cuda() == true);
36     TORCH_CHECK(d.index() == 1);
37 }

```

## 8.4.8 TensorOptions

See <https://github.com/pytorch/pytorch/blob/master/c10/core/TensorOptions.h>

### Constructors (not recommended)

Listing 24: ./code/tensor-options/main.cc (Not recommended constructors)

```

1 void TestConstructor() {
2     // not recommended
3     torch::TensorOptions opt1(torch::kCPU);
4     torch::TensorOptions opt2(torch::Device(torch::kCPU));
5     torch::TensorOptions opt3(torch::Device({torch::kCUDA, 1}));
6     torch::TensorOptions opt4("cpu");
7     // torch::TensorOptions opt5("CPU") // error;
8     torch::TensorOptions opt6("cuda:1");
9     // torch::TensorOptions opt7("CUDA:1"); // error
10
11     // not recommended, from a scalar type (implicit)
12     torch::TensorOptions opt8(torch::kInt32);
13 }

```

### Constructors (Recommended)

Listing 25: ./code/tensor-options/main.cc (Recommended constructors)

```

1 void TestConstructor2() {
2     // recommended
3     torch::TensorOptions opt1 = torch::dtype(torch::kFloat);
4     torch::TensorOptions opt2 = torch::dtype(caffe2::TypeMeta::Make<float>());
5     torch::TensorOptions opt3 = torch::device(torch::kCPU);
6     torch::TensorOptions opt4 = torch::device({torch::kCUDA, 1});
7     // Note: torch::device() returns a TensorOptions
8     // while torch::Device() is the constructor of a class
9
10    torch::TensorOptions opt5 = torch::requires_grad(true);
11    std::cout << opt5 << "\n";
12    // TensorOptions(dtype=float (default), device=cpu (default), layout=Strided
13    // (default), requires_grad=true, pinned_memory=false (default),
14    // memory_format=(nullopt))
15
16    torch::TensorOptions opt6 = torch::dtype<float>();
17    std::cout << torch::toString(opt6) << "\n";
18    // TensorOptions(dtype=float, device=cpu (default), layout=Strided (default),
19    // requires_grad=false (default), pinned_memory=false (default),
20    // memory_format=(nullopt))
21
22    std::cout << "default:" << torch::TensorOptions() << "\n";
23    // default:TensorOptions(dtype=float (default), device=cpu (default),
24    // layout=Strided (default), requires_grad=false (default),

```

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```

25 // pinned_memory=false (default), memory_format=(nullopt))
26 }

```

## Methods

Listing 26: ./code/tensor-options/main.cc (Methods)

```

1 void TestMethods() {
2     torch::TensorOptions opts = torch::dtype<float>();
3     TORCH_CHECK(opts.device() == torch::Device(torch::kCPU));
4     // It has not device_type!
5     TORCH_CHECK(opts.device() == torch::kCPU);
6     TORCH_CHECK(opts.device().type() == torch::kCPU);
7     TORCH_CHECK(opts.requires_grad() == false);
8
9     torch::TensorOptions opts2 =
10         opts.device("cuda:2").dtype(torch::kInt).requires_grad(false);
11
12     TORCH_CHECK(opts2.dtype() == caffe2::TypeMeta::Make<int32_t>());
13     TORCH_CHECK(opts2.dtype() == torch::kInt32);
14     TORCH_CHECK(opts2.requires_grad() == false);
15 }

```

## 8.4.9 Tensor Creation

See

### TensorDataContainer

---

**Note:** data is **copied** to the returned tensor!

---

See

- <https://github.com/pytorch/pytorch/blob/master/torch/csrc/api/include/torch/detail/TensorDataContainer.h>
- [https://github.com/pytorch/pytorch/blob/master/tools/autograd/templates/variable\\_factories.h](https://github.com/pytorch/pytorch/blob/master/tools/autograd/templates/variable_factories.h)
- <https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/Utils.cpp>

Support the following data types:

- From a `std::vector<T>`
- From a scalar
- From an initializer list
- From an `ArrayRef<T>`.

## From std::vector

Listing 27: ./code/tensor-creation/main.cc

```

1 static void FromStdVecotr() {
2     torch::Tensor t1 = torch::tensor(std::vector<int32_t>{1, 2, 3});
3     TORCH_CHECK(t1.scalar_type() == torch::kLong);
4     t1 = t1.to(torch::kInt);
5     const int32_t *p1 = t1.data_ptr<int32_t>();
6     TORCH_CHECK(p1[0] == 1);
7     TORCH_CHECK(p1[1] == 2);
8     TORCH_CHECK(p1[2] == 3);
9
10    torch::Tensor t2 = torch::tensor(std::vector<float>{1, 2, 3});
11    TORCH_CHECK(t2.scalar_type() == torch::kFloat);
12
13    torch::Tensor t3 =
14        torch::tensor(std::vector<double>{1, 2, 3}, torch::kDouble);
15    TORCH_CHECK(t3.scalar_type() == torch::kDouble);
16
17    torch::Tensor t4 =
18        torch::tensor(std::vector<double>{1, 2, 3},
19                      torch::dtype(torch::kDouble).device("cuda:0"));
20    TORCH_CHECK(t4.is_cuda());
21 }

```

## From scalar

Listing 28: ./code/tensor-creation/main.cc

```

1 static void FromScalar() {
2     torch::Tensor t = torch::tensor(3);
3     TORCH_CHECK(t.item<int64_t>() == 3);
4
5     torch::Tensor t2 = torch::tensor(0.5);
6     TORCH_CHECK(t2.scalar_type() == torch::kFloat);
7 }

```

## From initializer list

Listing 29: ./code/tensor-creation/main.cc

```

1 static void FromInitializerList() {
2     torch::Tensor t1 = torch::tensor({1, 2, 3});
3     torch::Tensor t2 = torch::tensor(std::vector<int32_t>{1, 2, 3});
4     TORCH_CHECK(torch::allclose(t1, t2));
5
6     torch::Tensor t3 = torch::tensor({{1, 2, 3}, {4, 5, 6}});
7     TORCH_CHECK(t3.dim() == 2);
8 }

```

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```

9  torch::Tensor t4 = torch::tensor({1, 2, 3});
10 torch::Tensor t5 = torch::tensor({4, 5, 6});
11 TORCH_CHECK(torch::allclose(t3[0], t4));
12 TORCH_CHECK(torch::allclose(t3[1], t5));
13 }

```

## From ArrayRef

Listing 30: ./code/tensor-creation/main.cc

```

1  static void FromArrayRef() {
2      int32_t i[] = {1, 2, 3};
3      torch::ArrayRef<int32_t> a(i);
4      torch::Tensor t = torch::tensor(a);
5      // Data is copied to t
6
7      TORCH_CHECK(t[0].item<int64_t>(), 1);
8      TORCH_CHECK(t[1].item<int64_t>(), 2);
9      TORCH_CHECK(t[2].item<int64_t>(), 3);
10 }

```

## 8.4.10 Tensor

See

- <https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/TensorBase.h>
- <https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/templates/TensorBody.h>
- <https://github.com/pytorch/pytorch/blob/master/c10/core/TensorImpl.h>

## Common methods

Listing 31: ./code/tensor/main.cc (Not recommended constructors)

```

1  static void TestCommonMethods() {
2      torch::Tensor t = torch::rand({2, 3, 4});
3
4      TORCH_CHECK(t.dim() == 3);           // 3-d tensor
5      TORCH_CHECK(t.ndimension() == t.dim()); // same
6      TORCH_CHECK(t.numel() == 2 * 3 * 4);
7      TORCH_CHECK(t.is_contiguous() == true);
8      TORCH_CHECK(t.contiguous().is_contiguous() == true);
9
10     t.fill_(10); // fill all entries to 0
11     t.zero_();   // zero out all entries
12
13     t = t.to(torch::kInt);
14     TORCH_CHECK(t.is_floating_point() == false);
15     TORCH_CHECK(t.is_signed() == true);

```

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```

16 TORCH_CHECK(t.size(0) == 2);
17 TORCH_CHECK(t.size(1) == 3);
18 TORCH_CHECK(t.size(2) == 4);
19 TORCH_CHECK(t.sizes() == torch::ArrayRef<int64_t>({2, 3, 4}));
20
21 t = t.contiguous();
22 TORCH_CHECK(t.stride(0) == 3 * 4);
23 TORCH_CHECK(t.stride(1) == 4);
24 TORCH_CHECK(t.stride(2) == 1);
25 TORCH_CHECK(t.strides() == torch::ArrayRef<int64_t>({12, 4, 1}));
26
27 TORCH_CHECK(t.defined() == true);
28 {
29     torch::Tensor a;
30     TORCH_CHECK(a.defined() == false);
31     a = t;
32     TORCH_CHECK(a.defined() == true);
33     a.reset();
34     TORCH_CHECK(a.defined() == false);
35 }
36
37 t = t.to(torch::kShort);
38 TORCH_CHECK(t.itemsize() == sizeof(int16_t));
39 TORCH_CHECK(t.nbytes() == t.numel() * t.itemsize());
40 TORCH_CHECK(t.itemsize() == t.element_size()); // same
41
42 TORCH_CHECK(t.scalar_type() == torch::kShort);
43 TORCH_CHECK(t.dtype() == caffe2::TypeMeta::Make<int16_t>());
44 TORCH_CHECK(t.dtype().toScalarType() == torch::kShort);
45
46 TORCH_CHECK(t.device() == torch::Device("cpu"));
47 TORCH_CHECK(t.device() == torch::Device(torch::kCPU));
48
49 // Note: t.device() return an instance of torch::Device
50 // t.get_device() returns the device index.
51 TORCH_CHECK(t.get_device() == t.device().index());
52
53 TORCH_CHECK(t.is_cpu() == true);
54 TORCH_CHECK(t.is_cuda() == false);
55
56 t = t.to(torch::kInt);
57 int32_t *p = t.data_ptr<int32_t>();
58 p[0] = 100;
59
60 torch::TensorAccessor<int32_t, 3> acc = t.accessor<int32_t, 3>();
61 TORCH_CHECK(acc[0][0][0] == p[0]);
62 p[12] = -2;
63 TORCH_CHECK(acc[1][0][0] == -2);
64
65 acc[1][1][2] = 3;
66 TORCH_CHECK(*(p + 12 + 4 + 2) == 3);
67

```

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```

68
69 t = t.to(torch::kFloat);
70 t.set_requires_grad(true);
71 TORCH_CHECK(t.requires_grad() == true);
72
73 t.set_requires_grad(false);
74 TORCH_CHECK(t.requires_grad() == false);
75
76 t = t.cuda();
77 TORCH_CHECK(t.device().type() == torch::kCUDA);
78 t = t.cpu();
79
80 torch::TensorOptions opts = t.options();
81 TORCH_CHECK(opts.device() == t.device());
82 }

```

## slice

Listing 32: torch::slice

```

1 static void TestSlice() {
2     auto t = torch::tensor({1, 2, 3, 4, 5}, torch::kInt);
3     torch::TensorAccessor<int32_t, 1> acc = t.accessor<int32_t, 1>();
4
5     // t2 = t[1:3]
6     torch::Tensor t2 = t.slice(/*dim*/ 0, /*start*/ 1,
7                               /*end, exclusive*/ 3); // memory is shared
8     torch::TensorAccessor<int32_t, 1> acc2 = t2.accessor<int32_t, 1>();
9     TORCH_CHECK(acc2[0] == 2);
10    TORCH_CHECK(acc2[1] == 3);
11
12    acc2[0] = 10; // also changes t since the memory is shared
13    TORCH_CHECK(acc[1] == 10);
14 }

```

## topk

Listing 33: torch::topk

```

1 // https://pytorch.org/docs/stable/generated/torch.topk.html
2 static void TestTopK() {
3     auto t = torch::tensor({1, 0, 3, -1}, torch::kInt).to(torch::kFloat);
4     torch::Tensor values, indexes;
5     std::tie(values, indexes) =
6         t.topk(/*k*/ 2, /*dim*/ 0, /*largest*/ true, /*sorted*/ true);
7     auto values_acc = values.accessor<float, 1>();
8     auto indexes_acc = indexes.accessor<int64_t, 1>(); // Note: it is int64_t
9
10    TORCH_CHECK(values.numel() == 2); // k in topk is 2

```

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```
11  TORCH_CHECK(values_acc[0] == 3); // the largest value is 3, at t[2]
12  TORCH_CHECK(values_acc[1] == 1); // the second largest value is 1, at t[0]
13  //
14  TORCH_CHECK(indexes_acc[0] == 2); // the largest value is t[2]
15  TORCH_CHECK(indexes_acc[1] == 0); // the second largest value is t[0]
16  }
```

## floor\_divide

Listing 34: torch::floor\_divide

```
1  static void TestFloorDivide() {
2      auto t = torch::tensor({1, 0, 3, 5, 9}, torch::kInt);
3      auto p = torch::floor_divide(t, 2);
4      auto acc = p.accessor<int32_t, 1>();
5      TORCH_CHECK(acc[0] == 1 / 2);
6      TORCH_CHECK(acc[1] == 0 / 2);
7      TORCH_CHECK(acc[2] == 3 / 2);
8      TORCH_CHECK(acc[3] == 5 / 2);
9      TORCH_CHECK(acc[4] == 9 / 2);
10 }
```

## div

Listing 35: torch::div

```

1 // https://pytorch.org/docs/stable/generated/torch.div.html
2 static void TestDiv() {
3     auto t = torch::tensor({1, 0, 3, 5, 9}, torch::kInt);
4     // the rounding mode is supported in torch >= 1.8.0
5     auto p = torch::div(t, 2, /*rounding_mode*/ "trunc");
6     auto acc = p.accessor<int32_t, 1>();
7     TORCH_CHECK(acc[0] == 1 / 2);
8     TORCH_CHECK(acc[1] == 0 / 2);
9     TORCH_CHECK(acc[2] == 3 / 2);
10    TORCH_CHECK(acc[3] == 5 / 2);
11    TORCH_CHECK(acc[4] == 9 / 2);
12 }

```

## remainder

Listing 36: torch::remainder

```

1 static void TestRemainder() {
2     auto t = torch::tensor({1, 3, 8}, torch::kInt);
3     auto p = torch::remainder(t, 3);
4     auto acc = p.accessor<int32_t, 1>();
5     TORCH_CHECK(acc[0] == 1);
6     TORCH_CHECK(acc[1] == 0);
7     TORCH_CHECK(acc[2] == 2);
8 }

```

## empty

Listing 37: torch::empty

```

1 static void TestEmpty() {
2     auto t = torch::empty({3}, torch::kInt);
3     TORCH_CHECK(t.scalar_type() == torch::kInt);
4     TORCH_CHECK(t.numel() == 3);
5 }

```

## stack

Listing 38: torch::stack

```

1 static void TestStack() {
2     auto t = torch::empty({6, 5}, torch::kInt);
3     auto a = torch::stack({t, t}, /*dim*/ 1);
4     TORCH_CHECK(a.sizes() == torch::ArrayRef<int64_t>({6, 2, 5}));
5
6     a = torch::stack({t, t}, /*dim*/ 0);

```

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```

7  TORCH_CHECK(a.sizes() == torch::ArrayRef<int64_t>({2, 6, 5}));
8
9  a = torch::stack({t, t}, /*dim*/ 2);
10 TORCH_CHECK(a.sizes() == torch::ArrayRef<int64_t>({6, 5, 2}));
11 }

```

## unbind

Listing 39: torch::unbind

```

1  static void TestUnbind() {
2      auto t = torch::empty({4, 6, 5}, torch::kInt);
3      std::vector<torch::Tensor> v = torch::unbind(t, /*dim*/ 1);
4      TORCH_CHECK(v.size() == t.size(1));
5      for (int32_t i = 0; i != v.size(); ++i) {
6          TORCH_CHECK(v[i].sizes() == torch::ArrayRef<int64_t>({4, 5}));
7      }
8  }

```

## full

Listing 40: torch::full

```

1  static void TestFull() {
2      auto t = torch::full({2, 3}, 10, torch::kInt);
3      const int32_t *p = t.data_ptr<int32_t>();
4      for (int32_t i = 0; i != t.numel(); ++i) {
5          TORCH_CHECK(p[i] == 10);
6      }
7  }

```

## split

Listing 41: torch::split

```

1  static void TestSplit() {
2      auto t = torch::arange(6).reshape({2, 3});
3      std::vector<torch::Tensor> s = t.split(1);
4      TORCH_CHECK(s.size() == 2);
5      TORCH_CHECK(s[0].sizes() == torch::ArrayRef<int64_t>({1, 3}));
6      TORCH_CHECK(s[1].sizes() == torch::ArrayRef<int64_t>({1, 3}));
7
8      s = t.split(1, /*dim*/ 1);
9      TORCH_CHECK(s.size() == 3);
10     TORCH_CHECK(s[0].sizes() == torch::ArrayRef<int64_t>({2, 1}));
11     TORCH_CHECK(s[1].sizes() == torch::ArrayRef<int64_t>({2, 1}));

```

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```

12 TORCH_CHECK(s[2].sizes() == torch::ArrayRef<int64_t>({2, 1}));
13 }

```

## zeros

Listing 42: torch::zeros

```

1 static void TestZeros() {
2     auto t = torch::zeros({2, 3}, torch::kFloat);
3     std::cout << t << "\n";

```

## cat

Listing 43: torch::cat

```

1 static void TestCat() {
2     auto t = torch::arange(24).reshape({2, 3, 4});
3     std::vector<torch::Tensor> v(5, t);
4     auto p = torch::cat(v, /*dim*/ 1);
5     TORCH_CHECK(p.sizes() == torch::ArrayRef<int64_t>({2, 3 * 5, 4}));
6 }

```

## division

Listing 44: test division

```

1 static void TestDivision() {
2     auto t = torch::arange(4).to(torch::kInt);
3     auto b = t / 2;
4     TORCH_CHECK(b.scalar_type() == torch::kFloat);
5
6     const float *p = b.data_ptr<float>();
7     TORCH_CHECK(p[0] == 0 / 2.);
8     TORCH_CHECK(p[1] == 1 / 2.);
9     TORCH_CHECK(p[2] == 2 / 2.);
10    TORCH_CHECK(p[3] == 3 / 2.);
11
12    auto c = b.to(torch::kInt);
13
14    const int32_t *q = c.data_ptr<int32_t>();
15    TORCH_CHECK(q[0] == 0 / 2);
16    TORCH_CHECK(q[1] == 1 / 2);
17    TORCH_CHECK(q[2] == 2 / 2);
18    TORCH_CHECK(q[3] == 3 / 2);
19 }

```

### 8.4.11 intrusive\_ptr

### 8.4.12 optional

### 8.4.13 PackedSequence

See

- <https://github.com/pytorch/pytorch/blob/master/torch/csrc/api/include/torch/nn/utils/rnn.h>
- <https://github.com/pytorch/pytorch/blob/master/torch/nn/utils/rnn.py>

### pack\_padded\_sequence

Listing 45: ./code/packed-sequence/main.cc

```

1  static void TestPadPackedSequence() {
2      torch::Tensor t = torch::tensor({
3          {{10, 20, 30}, {0, 0, 0}, {0, 0, 0}},
4          {{1, 2, 3}, {4, 5, 6}, {7, 8, 9}},
5          {{-1, 2, 3}, {-4, 5, 6}, {0, 0, 0}},
6      });
7      torch::Tensor lengths = torch::tensor({1, 3, 2});
8      torch::nn::utils::rnn::PackedSequence packed_seq =
9          torch::nn::utils::rnn::pack_padded_sequence(
10             t, lengths, /*batch_first*/ true, /*enforce_sorted*/ false);
11      std::cout << "data: " << packed_seq.data() << "\n";
12      std::cout << "batch_sizes: " << packed_seq.batch_sizes() << "\n";
13      std::cout << "sorted_indices: " << packed_seq.sorted_indices() << "\n";
14      std::cout << "unsorted_indices: " << packed_seq.unsorted_indices() << "\n";
15  }
16  /*
17  data:   1   2   3
18  -1   2   3
19  10  20  30
20   4   5   6
21  -4   5   6
22   7   8   9
23  [ CPULongType{6,3} ]
24  batch_sizes:  3
25   2
26   1
27  [ CPULongType{3} ]
28  sorted_indices:  1
29   2
30   0
31  [ CPULongType{3} ]
32  unsorted_indices:  2
33   0
34   1
35  [ CPULongType{3} ]
36  */

```

The output is

Listing 46: ./code/packed-sequence/main.cc

```

1 }
2 /*
3 data:  1  2  3
4   -1  2  3
5   10 20 30
6    4  5  6
7   -4  5  6
8    7  8  9
9 [ CPULongType{6,3} ]
10 batch_sizes:  3
11   2
12   1
13 [ CPULongType{3} ]
14 sorted_indices: 1
15   2

```

#### 8.4.14 ivalue

Listing 47: ./code/ivalue/main.cc

```

1 #include "torch/script.h"
2
3 static void TestVectorOfTensor() {
4     torch::jit::Module m("m");
5     m.define(R"(
6         def forward(self, x, y):
7             return [x, y]
8     )");
9     auto x = torch::tensor({1, 2, 3});
10    auto y = torch::tensor({4, 5, 6});
11    auto i = m.run_method("forward", x, y);
12
13    assert(i.tagKind() == "GenericList");
14
15    torch::ArrayRef<torch::IValue> tensor_list = i.toListRef();
16    TORCH_CHECK(torch::allclose(x, tensor_list[0].toTensor()));
17    TORCH_CHECK(torch::allclose(y, tensor_list[1].toTensor()));
18
19    torch::List<torch::IValue> k = i.toList();
20
21    torch::List<torch::Tensor> o =
22        c10::impl::toTypedList<torch::Tensor>(std::move(k));
23
24    TORCH_CHECK(torch::allclose(o[0], x));
25    TORCH_CHECK(torch::allclose(o[1], y));
26
27    std::vector<torch::Tensor> p = o.vec();
28    TORCH_CHECK(torch::allclose(p[0], x));
29    TORCH_CHECK(torch::allclose(p[1], y));

```

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```

30 }
31
32 static void TestVectorOfTensor2() {
33     torch::jit::Module m("m");
34     m.define(R"(
35         def forward(self, x):
36             return [[x], [x,x]]
37     )");
38     auto x = torch::tensor({1, 2, 3});
39     auto i = m.run_method("forward", x);
40     TORCH_CHECK(i.tagKind() == "GenericList");
41
42     torch::List<torch::IValue> list = i.toList();
43     torch::Tensor a = list.get(0).toListRef()[0].toTensor();
44     TORCH_CHECK(torch::allclose(a, x));
45
46     std::vector<torch::Tensor> b =
47         c10::impl::toTypedList<torch::Tensor>(list.get(1).toList()).vec();
48     TORCH_CHECK(torch::allclose(b[0], x));
49     TORCH_CHECK(torch::allclose(b[1], x));
50 }
51
52 static void TestVectorOfTensor3() {
53     torch::jit::Module m("m");
54     m.define(R"(
55         def forward(self, x: List[torch.Tensor]):
56             return x[0] + x[1]
57     )");
58
59     std::vector<torch::Tensor> v;
60     v.push_back(torch::tensor({1, 2}));
61     v.push_back(torch::tensor({3, 4}));
62     c10::List<torch::Tensor> ilist(v);
63
64     c10::impl::GenericList generic_list = c10::impl::toList(ilist);
65
66     c10::List<torch::Tensor> l2 =
67         c10::impl::toTypedList<torch::Tensor>(generic_list);
68
69     TORCH_CHECK(torch::allclose(l2[0], v[0]));
70     TORCH_CHECK(torch::allclose(l2[1], v[1]));
71
72     auto r = m.run_method("forward", generic_list);
73     TORCH_CHECK(torch::allclose(r.toTensor(), v[0] + v[1]));
74
75     // Note: We can pass a vector directly
76     r = m.run_method("forward", v);
77     TORCH_CHECK(torch::allclose(r.toTensor(), v[0] + v[1]));
78
79     r = m.run_method("forward", ilist); // also OK
80     TORCH_CHECK(torch::allclose(r.toTensor(), v[0] + v[1]));
81 }

```

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```

82
83 static void TestVectorOfTensor4() {
84     torch::jit::Module m("m");
85     m.define(R"(
86         def forward(self, x: Tuple[List[torch.Tensor]]):
87             return x[0][0] + x[0][1]
88     )");
89
90     std::vector<torch::Tensor> v;
91     v.push_back(torch::tensor({1, 2}));
92     v.push_back(torch::tensor({3, 4}));
93     auto t = torch::ivalue::Tuple::create(v);
94
95     auto r = m.run_method("forward", t);
96     TORCH_CHECK(torch::allclose(r.toTensor(), v[0] + v[1]));
97 }
98
99 static void TestVectorOfTensor5() {
100     torch::jit::Module m("m");
101     m.define(R"(
102         def forward(self, x: Tuple[List[List[torch.Tensor]], List[torch.Tensor]]):
103             return x[0][0][0] + x[0][0][1] + x[1][0] + x[1][1]
104     )");
105
106     std::vector<torch::Tensor> v;
107     v.push_back(torch::tensor({1, 2}));
108     v.push_back(torch::tensor({3, 4}));
109
110     std::vector<std::vector<torch::Tensor>> vv;
111     vv.push_back(v);
112     vv.push_back(v);
113
114     auto t = torch::ivalue::Tuple::create(vv, v);
115
116     auto r = m.run_method("forward", t);
117     TORCH_CHECK(torch::allclose(r.toTensor(), v[0] + v[1] + v[0] + v[1]));
118 }
119
120 static void TestVectorOfTensor6() {
121     // List[List[Tensor]]
122     std::vector<torch::Tensor> v;
123     v.push_back(torch::tensor({1, 2}));
124     v.push_back(torch::tensor({3, 4}));
125
126     c10::List<torch::Tensor> ilist(v);
127     torch::IValue ivalue(ilist);
128     TORCH_CHECK(ivalue.tagKind() == "GenericList");
129
130     c10::List<c10::List<torch::Tensor>> ilist2(ilist);
131     ilist2.push_back(ilist);
132     ilist2.push_back(ilist);
133

```

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```

134 torch::IValue ivalue2(ilst2);
135 TORCH_CHECK(ivalue2.tagKind() == "GenericList");
136
137 c10::List<torch::IValue> a0 = ivalue2.toList();
138 c10::List<c10::List<torch::Tensor>> a1 =
139     c10::impl::toTypedList<c10::List<torch::Tensor>>(a0);
140
141 c10::ArrayRef<torch::IValue> a = ivalue2.toListRef();
142
143 torch::List<torch::Tensor> b =
144     c10::impl::toTypedList<torch::Tensor>(a[0].toList());
145 for (int32_t i = 0; i != b.size(); ++i) {
146     std::cout << b[i] << "\n";
147 }
148 std::vector<std::vector<torch::Tensor>> v2{v};
149 torch::List<torch::List<torch::Tensor>> c;
150 for (auto k : v2) {
151     c10::List<torch::Tensor> dd{torch::ArrayRef<torch::Tensor>(k)};
152     c.push_back(std::move(dd));
153 }
154 }
155
156 int main() {
157     TestVectorOfTensor();
158     TestVectorOfTensor2();
159     TestVectorOfTensor3();
160     TestVectorOfTensor4();
161     TestVectorOfTensor5();
162     TestVectorOfTensor6();
163     return 0;
164 }

```

## 8.4.15 method

See:

- <https://github.com/pytorch/pytorch/blob/master/torch/csrc/api/include/torch/imethod.h>

Listing 48: ./code/method/main.cc

```

1  #include "torch/script.h"
2
3  static void TestHello() {
4      torch::jit::Module m("m");
5      m.define(R"(
6          def forward(self, x: torch.Tensor, y: torch.Tensor):
7              return x + y
8      )");
9
10     torch::jit::Method method = m.get_method("forward");
11     TORCH_CHECK(method.name() == "forward");

```

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```

12
13 const std::vector<std::string> &names = method.getArgumentNames();
14 TORCH_CHECK(names.size() == 2);
15 TORCH_CHECK(names[0] == "x");
16 TORCH_CHECK(names[1] == "y");
17
18 std::vector<torch::IValue> args;
19 auto x = torch::tensor({1, 2});
20 auto y = torch::tensor({1, 2});
21 args.emplace_back(x);
22 args.emplace_back(y);
23 auto z = method(args).toTensor();
24
25 TORCH_CHECK(torch::equal(z, x + y));
26
27 std::shared_ptr<torch::jit::Graph> g = method.graph();
28 // see node/main.cc
29 }
30
31 int main() {
32     TestHello();
33     return 0;
34 }

```

## 8.4.16 type

See: - [https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/jit\\_type\\_base.h](https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/jit_type_base.h) -  
[https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/jit\\_type.h](https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/jit_type.h) - [https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/jit\\_type.h](https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/jit_type.h)

torch::Type contains a member torch::TypeKind. torch::SharedType is a subclass of torch::Type and std::enabled\_shared\_from\_this<torch::SharedType>.

```

// https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/jit_type_base.h#L637
using TypePtr = SingletonOrSharedTypePtr<Type>;

```

Listing 49: ./code/type/main.cc

```

1 #include "torch/script.h"
2
3 static void TestTypeKind() {
4     // https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/jit_type_base.h
5     torch::TypeKind k = torch::TypeKind::AnyType;
6     TORCH_CHECK(torch::typeKindToString(k) == std::string("AnyType"));
7
8     // NamedType is not a member of TypeKind
9 }
10
11 static void TestNumberType() {
12     // torch::NumberType::get() returns a static object!
13     // so p and q are actually the same
14     torch::NumberTypePtr p = torch::NumberType::get();

```

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```

15 torch::NumberTypePtr q = torch::NumberType::get();
16
17 TORCH_CHECK(p.get() == q.get());
18
19 TORCH_CHECK(p->str() == "Scalar");
20 TORCH_CHECK(p->kind() == torch::NumberType::Kind);
21 TORCH_CHECK(p->kind() == torch::TypeKind::NumberType);
22 }
23
24 static void TestIntType() {
25     torch::IntTypePtr p = torch::IntType::get();
26     TORCH_CHECK(p->str() == "int");
27     TORCH_CHECK(p->kind() == torch::TypeKind::IntType);
28     TORCH_CHECK(p->kind() == torch::IntType::Kind);
29     TORCH_CHECK(p->isSubtypeOf(torch::NumberType::get()) == true);
30 }
31
32 static void TestFloatType() {
33     torch::FloatTypePtr p = torch::FloatType::get();
34     TORCH_CHECK(p->str() == "float");
35     TORCH_CHECK(p->kind() == torch::TypeKind::FloatType);
36     TORCH_CHECK(p->kind() == torch::FloatType::Kind);
37     TORCH_CHECK(p->isSubtypeOf(torch::NumberType::get()) == true);
38     TORCH_CHECK(p->isSubtypeOf(torch::IntType::get()) == false);
39 }
40
41 static void TestBoolType() {
42     torch::BoolTypePtr p = torch::BoolType::get();
43     TORCH_CHECK(p->str() == "bool");
44     TORCH_CHECK(p->kind() == torch::TypeKind::BoolType);
45     TORCH_CHECK(p->kind() == torch::BoolType::Kind);
46     TORCH_CHECK(p->isSubtypeOf(torch::NumberType::get()) == true);
47     TORCH_CHECK(p->isSubtypeOf(torch::IntType::get()) == false);
48 }
49
50 static void TestNamedType() {
51     // torch::Type is an abstract class!
52     //
53     // torch::NamedType is an abstract class!
54     //
55     // torch::NamedType t(torch::TypeKind::AnyType, "foo.bar"); // error
56     // TORCH_CHECK(t.name()->qualifiedName() == "foo.bar");
57 }
58
59 static void TestAnyType() {
60     torch::AnyTypePtr p = torch::AnyType::get();
61     TORCH_CHECK(p->Kind == torch::TypeKind::AnyType);
62     TORCH_CHECK(p->kind() == torch::TypeKind::AnyType);
63     TORCH_CHECK(p->str() == "Any");
64     TORCH_CHECK(p->requires_grad() == false);
65
66     TORCH_CHECK(p == torch::AnyType::get());

```

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```

67
68 // available in newer versions of PyTorch
69 // TORCH_CHECK(p->equals(torch::AnyType::get()));
70
71 TORCH_CHECK(torch::toString(p) == "Any");
72 }
73
74 int main() {
75     TestTypeKind();
76     TestNumberType();
77     TestIntType();
78     TestFloatType();
79     TestNamedType();
80     TestAnyType();
81     return 0;
82 }

```

### 8.4.17 trace

Listing 50: ./code/trace/ex0.py

```

1  #!/usr/bin/env python3
2
3  import torch
4
5  import torch.nn as nn
6  from typing import List
7
8
9  class Foo(nn.Module):
10     def __init__(self):
11         super().__init__()
12         self.relu = nn.ReLU()
13
14     def forward(self, x):
15         return self.relu(x)
16
17
18 def test_foo():
19     f = Foo()
20     m = torch.jit.trace(f, torch.rand(2, 3))
21
22     print(m(torch.rand(2)))
23     print(m(torch.rand(2, 3, 4)))
24     # Note: The input shape is dynamic, not fixed.
25
26
27 def simple(x: List[torch.Tensor], y: torch.Tensor):
28     x = x[0].item()
29     if x > 2:

```

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```

30     return y + x + 1
31 elif x < 1:
32     return y
33 else:
34     return y + x
35
36
37 def test_simple():
38     f0 = torch.jit.trace(simple, ([torch.tensor([0])], torch.rand(2, 3)))
39     # print(dir(f0))
40     """
41     ['__call__', '__class__', '__delattr__', '__dict__', '__dir__', '__doc__',
42     '__eq__', '__format__', '__ge__', '__getattribute__', '__gt__', '__hash__',
43     '__init__', '__init_subclass__', '__le__', '__lt__', '__module__', '__ne__',
44     '__new__', '__reduce__', '__reduce_ex__', '__repr__', '__setattr__',
45     '__sizeof__', '__str__', '__subclasshook__', '_debug_flush_compilation_cache',
46     'code', 'get_debug_state', 'graph', 'graph_for', 'inlined_graph', 'name',
47     'qualified_name', 'save', 'save_to_buffer', 'schema']
48     """
49     # print(f0.schema) # simple(Tensor[] x, Tensor y) -> (Tensor)
50     # print(f0.code)
51     """
52     def simple(x: List[Tensor],
53               y: Tensor) -> Tensor:
54         return y
55     """
56     # print(f0.graph)
57     """
58     graph(%x : Tensor[],
59           %y : Float(2, 3, strides=[3, 1], requires_grad=0, device=cpu)):
60         return (%y)
61     """
62     # print(f0.inlined_graph) # same as the above one
63     # print(f0.name) # simple
64     print(f0.qualified_name) # __torch__.simple
65
66
67 def main():
68     # test_foo()
69     test_simple()
70
71
72 if __name__ == "__main__":
73     main()

```

Listing 51: ./code/trace/ex1.py

```

1  #!/usr/bin/env python3
2
3  import torch
4
5

```

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```

6  def f(a, b):
7      c = a + b
8      d = c * c
9      e = torch.tanh(d * c)
10     return d + (e + e)
11
12
13 m = torch.jit.script(f)
14 print(m.graph)
15
16 """
17 graph(%a.1 : Tensor,
18       %b.1 : Tensor):
19     %4 : int = prim::Constant[value=1]()
20     %c.1 : Tensor = aten::add(%a.1, %b.1, %4) # ./ex1.py:7:8
21     %d.1 : Tensor = aten::mul(%c.1, %c.1) # ./ex1.py:8:8
22     %11 : Tensor = aten::mul(%d.1, %c.1) # ./ex1.py:9:19
23     %e.1 : Tensor = aten::tanh(%11) # ./ex1.py:9:8
24     %17 : Tensor = aten::add(%e.1, %e.1, %4) # ./ex1.py:10:16
25     %19 : Tensor = aten::add(%d.1, %17, %4) # ./ex1.py:10:11
26     return (%19)
27 """
28
29 """
30 Note: for aten::add(a0, a1, a2), it does a0 + a2 * a1.
31 See torch/csrc/jit/codegen/fuser/codegen.cpp
32
33 """
34 assert isinstance(m.graph, torch._C.Graph)
35
36 # Every graph has inputs and outputs
37 # m.graph.inputs() returns an iterator
38 assert len(list(m.graph.inputs())) == 2, "It has two inputs: a, b, in our case"
39 it = m.graph.inputs()
40 a = next(it)
41 b = next(it)
42
43 assert isinstance(a, torch._C.Value)
44 assert isinstance(a.node(), torch._C.Node)
45
46 # every node has inputs and outputs
47 # a.node().inputs() is an iterator
48 assert list(a.node().inputs()) == []
49 assert a.node().kind() == "prim::Param"
50 assert a.node().inputsSize() == 0
51 assert a.node().outputsSize() == 2
52 print(next(a.node().outputs()))
53
54 oit = a.node().outputs()
55 assert next(oit) == a
56 assert next(oit) == b
57

```

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```

58 assert next(a.node().outputs()) == a
59
60 assert a.node().outputsAt(0) == a
61 assert a.node().outputsAt(1) == b
62 assert a.node() == b.node()
63 assert a.node().attributeNames() == [], "this node has no attributes"
64 assert a.debugName() == "a.1"
65 assert isinstance(a.type(), torch._C.TensorType)
66 assert a.type().kind() == "TensorType"
67 assert a.unique() == 0 # TODO(fangjun): what does it mean?
68 assert isinstance(a.uses(), list)
69 assert isinstance(a.uses()[0], torch._C.Use)
70 assert isinstance(a.uses()[0].user, torch._C.Node)
71
72 c_node = a.uses()[0].user
73 assert c_node.kind() == "aten::add"
74 assert c_node.attributeNames() == []
75 assert len(list(c_node.inputs())) == 3
76 c_it = c_node.inputs()
77 assert a == next(c_it)
78 assert b == next(c_it)
79 v4 = next(c_it)
80 assert v4.debugName() == "4"
81 assert c_node.hasAttributes() is False
82 assert c_node.hasMultipleOutputs() is False
83 assert c_node.hasUses() is True
84 assert (
85     c_node.schema()
86     == "aten::add.Tensor(Tensor self, Tensor other, *, Scalar alpha=1) -> (Tensor)"
87 )
88 print(c_node.schema())
89 print(type(c_node.schema()))
90 v4_node = v4.node()
91 assert v4_node.attributeNames() == ["value"]
92 assert v4_node.hasAttributes() is True
93 assert v4_node.hasAttribute("value") is True
94 # print(v4_node.t("value"))
95 print(dir(v4_node))

```

## 8.4.18 Node

Listing 52: ./code/node/main.cc

```

1 #include "torch/csrc/jit/passes/quantization/helper.h" // for removeTorchMangle
2 #include "torch/script.h"
3
4 static void TestRemoveTorchMangle() {
5     std::string s = torch::jit::removeTorchMangle("a.__torch_mangle_1.foo");
6     TORCH_CHECK(s == "a.foo");
7 }

```

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```

8   s = torch::jit::removeTorchMangle("a.__torch_mangle_123.foo");
9   TORCH_CHECK(s == "a.foo");
10 }
11
12 static void TestSimple() {
13     torch::jit::Module m("m");
14     m.define(R"(
15         def forward(self, x: torch.Tensor, y: torch.Tensor):
16             a = x + 2
17             b = y * 3
18             return a + b
19     )");
20     std::shared_ptr<torch::jit::Graph> graph = m.get_method("forward").graph();
21     std::cout << "graph string: \n" << graph->toString() << "\n";
22     // Or we can use graph->dump();
23     torch::jit::Block *block = graph->block();
24     for (auto it = block->nodes().begin(), end = block->nodes().end();
25          it != end;) {
26         torch::jit::Node *n = *it++;
27         torch::jit::NodeKind k = n->kind();
28         std::cout << "node kind: " << k << " " << k.toQualString() << "\n";
29     }
30     #if 0
31     graph string:
32     graph(%self : __torch__.m,
33          %x.1 : Tensor,
34          %y.1 : Tensor):
35         %5 : int = prim::Constant[value=1]()
36         %4 : int = prim::Constant[value=2]() # <string>:3:14
37         %8 : int = prim::Constant[value=3]() # <string>:4:14
38         %a.1 : Tensor = aten::add(%x.1, %4, %5) # <string>:3:10
39         %b.1 : Tensor = aten::mul(%y.1, %8) # <string>:4:10
40         %13 : Tensor = aten::add(%a.1, %b.1, %5) # <string>:5:13
41         return (%13)
42
43     node kind: 14 prim::Constant
44     node kind: 14 prim::Constant
45     node kind: 14 prim::Constant
46     node kind: 534 aten::add
47     node kind: 241 aten::mul
48     node kind: 534 aten::add
49     #endif
50 }
51
52 static void TestFunctionCall() {
53     torch::jit::Module m("m");
54     m.define(R"(
55         def add(self, x: torch.Tensor, y: torch.Tensor):
56             '''my add doc'''
57             return x + y + 3
58
59         def forward(self, x: torch.Tensor, y: torch.Tensor):

```

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```

60     c = self.add(x, y)
61     return c
62 );
63 std::shared_ptr<torch::jit::Graph> graph = m.get_method("forward").graph();
64 std::cout << "graph string: \n" << graph->toString() << "\n";
65 torch::jit::Block *block = graph->block();
66 for (auto it = block->nodes().begin(), end = block->nodes().end();
67      it != end;) {
68     torch::jit::Node *n = *it++;
69     torch::jit::NodeKind k = n->kind();
70     std::cout << "node kind: " << k << " " << k.toQualString() << "\n";
71 }
72 #if 0
73 graph string:
74 graph(%self.1 : __torch__.m,
75       %x.1 : Tensor,
76       %y.1 : Tensor):
77   %c.1 : Tensor = prim::CallMethod[name="add"](%self.1, %x.1, %y.1) # <string>:6:10
78   return (%c.1)
79
80 node kind: 149 prim::CallMethod
81 #endif
82 for (auto it = block->nodes().begin(), end = block->nodes().end();
83      it != end;) {
84     torch::jit::Node *n = *it++;
85     torch::jit::NodeKind k = n->kind();
86     if (k == c10::prim::CallMethod) {
87         torch::ArrayRef<torch::jit::Value *> inputs = n->inputs();
88         TORCH_CHECK(inputs.size() == 3);
89
90         torch::jit::TypePtr type = inputs[0]->type();
91
92         auto class_type = type->cast<torch::jit::ClassType>();
93         TORCH_CHECK(class_type->str() == "__torch__.m");
94         if (!class_type) {
95             std::cout << "Not a class type: " << type->str() << "\n";
96             continue;
97         }
98         // defined by the macro "CREATE_ACCESSOR()" in ir/ir.h
99         const std::string &function_name = n->s(c10::attr::name);
100        // const std::string &function_name = n->s(torch::jit::attr::name);
101        TORCH_CHECK(function_name == "add");
102
103        TORCH_CHECK(torch::jit::attr::name == c10::attr::name);
104
105        torch::jit::Function &function = class_type->getMethod(function_name);
106        if (!function.isGraphFunction()) {
107            std::cout << function_name << " is not a graph function"
108                << "\n";
109            continue;
110        }
111        std::string class_type_str =

```

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```

112     torch::jit::removeTorchMangle(class_type->str());
113     // remove __torch__, which is 10 characters long
114     std::string no_torch_class_type_str = class_type_str.substr(10);
115 }
116 }
117 }
118
119 int main() {
120     // TestRemoveTorchMangle();
121     // TestSimple();
122     TestFunctionCall();
123     return 0;
124 }

```

### 8.4.19 symbol

See

- <https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/symbol.h>
- [https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/interned\\_strings.h](https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/interned_strings.h)

### 8.4.20 graph

Listing 53: ./code/graph/main.cc

```

1  #include "torch/script.h"
2
3  static void TestConv2d() {
4      torch::jit::Module m("m");
5      m.define(R"(
6          def __init__(self):
7              self.conv = torch.nn.Conv2d(2, 3)
8          def forward(self, x: torch.Tensor):
9              return self.conv(x)
10     )");
11     torch::jit::Method method = m.get_method("forward");
12     std::shared_ptr<torch::jit::Graph> g = method.graph();
13     torch::ArrayRef<torch::jit::Value*> inputs = g->inputs();
14     torch::ArrayRef<torch::jit::Value*> outputs = g->outputs();
15     TORCH_CHECK(inputs.size() == 1);
16     TORCH_CHECK(outputs.size() == 1);
17
18     torch::jit::Value *in = inputs[0];
19     std::cout << in->type()->str() << "\n";
20     std::cout << in->debugName() << "\n";
21 }
22
23 int main() {
24     TestConv2d();

```

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```
25     return 0;  
26 }
```

Listing 54: ./code/graph/inline\_calls.py

```
1  #!/usr/bin/env python3  
2  
3  from pathlib import Path  
4  
5  import torch  
6  import torch.nn as nn  
7  
8  
9  class Foo(nn.Module):  
10     def __init__(self):  
11         super().__init__()  
12         self.linear = nn.Linear(2, 2)  
13         self.linear2 = nn.Linear(2, 2)  
14         self.relu = nn.ReLU()  
15         self.t = torch.rand(2)  
16  
17     def forward(self, x: torch.Tensor):  
18         y = self.linear(x + self.t)  
19         y = self.linear2(y)  
20         y = self.linear2(y)  
21         # z = self.relu(y)  
22         return nn.functional.elu(y)  
23         return z  
24  
25  
26 def generate_foo_pt():  
27     f = Foo()  
28     x = torch.rand(1, 2)  
29     m = torch.jit.trace(f, x)  
30     m.save("foo.pt")  
31  
32  
33 def test_foo_pt():  
34     m = torch.jit.load("foo.pt")  
35     assert isinstance(m.forward, torch._C.ScriptMethod)  
36     assert isinstance(m.forward.graph, torch._C.Graph)  
37     assert isinstance(m.forward.inlined_graph, torch._C.Graph)  
38  
39     print(m.linear.graph)  
40     return  
41  
42     print(m.forward.graph)  
43     # print(m.forward.inlined_graph)  
44     g = m.forward.graph  
45     nodes = g.nodes()  
46  
47     n = next(nodes)
```

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```

48 print(dir(n))
49 assert n.kind() == "prim::GetAttr"
50 for i in n.inputs():
51     assert isinstance(i, torch._C.Value)
52     assert i.debugName() == "self.1"
53     assert isinstance(i.type(), torch._C.ClassType)
54     t = i.type()
55     assert t.str() == "__torch__.Foo"
56
57
58 def main():
59     generate_foo_pt()
60     # test_foo_pt()
61
62
63 if __name__ == "__main__":
64     main()

```

## 8.5 Logical operations

Listing 55: ./code/logical-op.py

```

1  #!/usr/bin/env python3
2
3  import torch
4
5  a = torch.tensor([float("inf")])
6  b = torch.tensor([float("nan")])
7  assert torch.isinf(a).item() is True
8  assert torch.isnan(a).item() is False
9
10 assert torch.isinf(b).item() is False
11 assert torch.isnan(b).item() is True
12
13 assert torch.logical_or(torch.isinf(a), torch.isnan(b)).item() is True
14
15 assert a.isinf().item() is True
16 assert a.isnan().item() is False
17
18 assert b.isinf().item() is False
19 assert b.isnan().item() is True

```

## 8.6 Note

To clip gradient, use:

```
tot_norm = torch.nn.utils.clip_grad_norm_(model.parameters(), max_norm=5, norm_type=2.0)
if torch.logical_or(tot_norm.isnan(), tot_norm.isinf()):
    # skip this update
    continue
else:
    optimizer.step()
```

## 8.7 Quantization

### 8.7.1 Internals

<https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/QuantizerBase.h> defines the base class Quantizer.

<https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/quantized/Quantizer.h> defines the subclasses of Quantizer, such as

- PerTensorAffineQuantizer - qscheme is kPerTensorAffine.

### QScheme

See <https://github.com/pytorch/pytorch/blob/master/c10/core/QScheme.h>

Listing 56: ./code/qscheme/main.cc

```
1  #include "torch/script.h"
2
3  static void TestQScheme() {
4      TORCH_CHECK(torch::toString(torch::kPerTensorAffine) == "per_tensor_affine");
5
6      TORCH_CHECK(torch::toString(torch::kPerChannelAffine) ==
7                  "per_channel_affine");
8
9      TORCH_CHECK(torch::toString(torch::kPerTensorSymmetric) ==
10                 "per_tensor_symmetric");
11
12     TORCH_CHECK(torch::toString(torch::kPerChannelSymmetric) ==
13                 "per_channel_symmetric");
14
15     TORCH_CHECK(torch::toString(torch::kPerChannelAffineFloatQParams) ==
16                 "per_channel_affine_float_qparams");
17 }
18
19 int main() {
20     TestQScheme();
21     return 0;
22 }
```

## PerTensorAffineQuantizer

It has 4 important methods:

- `QScheme qscheme() const`, always returns `kPerTensorAffine`.
- `double scale() const`
- `int64_t zero_point() const`
- `ScalarType scalar_type() const`

It uses `quantize_tensor_per_tensor_affine_cpu` when `FBGEMM` is available.

Otherwise, it uses <https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/native/quantized/cpu/kernels/QuantizedOpKernels.cpp>

- For arm, it uses `quantize_tensor_arm`. It is a template with many specializations.
- For x86, it uses `quantize_val`
  - If `FBGEMM` is available, it uses `quantize_val`
  - Otherwise, it uses <https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/native/quantized/AffineQuantizerBase.cpp>

```
template <typename T>
T quantize_val(double scale, int64_t zero_point, float value) {
    // std::nearbyint results in nearest integer value according to the current
    // rounding mode and the default rounding mode is rounds to even in half-way
    // cases in most popular processor architectures like x86 and ARM. This is
    // typically faster than an alternatives like std::round that rounds half-way
    // cases away from zero, and can be consistent with SIMD implementations for
    // example in x86 using _mm512_cvtps_epi32 or mm512_round_ps with
    // _MM_FROUND_CUR_DIRECTION option that also follow the current rounding mode.
    int64_t qvalue;
    constexpr int64_t qmin = std::numeric_limits<typename T::underlying>::min();
    constexpr int64_t qmax = std::numeric_limits<typename T::underlying>::max();
    float inv_scale = 1.0f / static_cast<float>(scale);
    qvalue = static_cast<int64_t>(zero_point + Round(value * inv_scale));
    qvalue = std::max<int64_t>(qvalue, qmin);
    qvalue = std::min<int64_t>(qvalue, qmax);
    return static_cast<T>(qvalue);
}
```

`dequantize_val` is defined as:

```
template <typename T>
TORCH_API float dequantize_val(double scale, int64_t zero_point, T value) {
    return static_cast<float>(scale) * (value.val_ - static_cast<int32_t>(zero_point));
}
```

## 8.7.2 torch.quantize\_per\_tensor

See [https://pytorch.org/docs/stable/generated/torch.quantize\\_per\\_tensor.html](https://pytorch.org/docs/stable/generated/torch.quantize_per_tensor.html)

```
def test_quantize_per_tensor():
    scale = 0.1
    zero_point = 1
    a = torch.tensor([10.0, 2.0], dtype=torch.float32)
    q = torch.quantize_per_tensor(
        input=a,
        scale=scale,
        zero_point=zero_point,
        dtype=torch.qint8,
    )
    assert isinstance(q, torch.Tensor)
    assert q.is_quantized is True

    assert q.q_scale() == scale
    assert q.q_zero_point() == zero_point
    assert str(q.qscheme()) == "torch.per_tensor_affine"
    assert q.dtype == torch.qint8

    c = q.int_repr()
    assert c[0] == a[0] / scale + zero_point
    assert c[1] == a[1] / scale + zero_point
    assert torch.all(torch.eq(c, torch.tensor([101, 21], dtype=torch.int8)))
    d = q.dequantize()
    assert d.dtype == torch.float32
    assert torch.all(torch.eq(d, a))

    f = torch.dequantize(q)
    assert torch.all(torch.eq(f, a))
    # print(q)
    """
    tensor([10.,  2.], size=(2,), dtype=torch.qint8,
           quantization_scheme=torch.per_tensor_affine, scale=0.1, zero_point=1)
    """
    assert q[0].item() == 10 # q[0].item() will dequantize() to a float
    assert q[1].item() == 2
    print(type(q[0].item()))
    q[0] = 2.5 # Note: it will quantize 2.5 and store it in q
    print(q.int_repr())
    """
    tensor([26, 21], dtype=torch.int8)
    """
```



## Compress ration

```
def test_size():
    r = torch.rand(100, 100, dtype=torch.float32)
    q = torch.quantize_per_tensor(r, scale=0.1, zero_point=0, dtype=torch.qint8)
    torch.save(r, "float32.pt")
    torch.save(q, "int8.pt")
    float_size = os.path.getsize("float32.pt")
    int8_size = os.path.getsize("int8.pt")
    print("float_size:", float_size)
    print("int8_size:", int8_size)
    print(f"ratio: {float_size}/{int8_size}: {float_size/int8_size:.3f}")
    os.remove("float32.pt")
    os.remove("int8.pt")
    """
    float_size: 40747
    int8_size: 10795
    ratio: 40747/10795: 3.775
    """
```

## 8.7.3 quantize\_per\_tensor\_dynamic

Listing 57: ./code/quantize\_per\_tensor\_dynamic/main.cc

```
1 // #include "ATen/native/quantized/cpu/QuantUtils.h" // for the latest pytorch
2
3 #include "ATen/native/quantized/cpu/quant_utils.h" // for torch 1.10
4 #include "ATen/ops/quantize_per_tensor_dynamic.h" // needs torch>=1.11
5 #include "torch/script.h"
6
7 // See
8 // https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/native/quantized/cpu/
9 // QuantUtils.h#L59
10 static void TestChooseQuantizationParams() {
11     quant_utils::TensorQuantizationParams p;
12     p = quant_utils::ChooseQuantizationParams(-1 /*min*/, 2 /*max*/,
13                                              -128 /*qmin*/, 127 /*qmax*/);
14     std::cout << "zero_point: " << p.zero_point << "\n";
15     std::cout << "scale: " << p.scale << "\n";
16     /**
17      * scale = (max - min) / (qmax - qmin) = 3 / 255 = 0.0117647
18      * zero_point_min = qmin - min/scale = -128 - (-1)/scale = -43
19      * zero_point_max = qmax - max/scale = 127 - 2/scale = -43
20      *
21      * min_error = abs(qmin) - abs(min/scale) = 128 - 1/scale = 43
22      * max_error = abs(qmax) - abs(max/scale) = 127 - 2/scale = -43
23      *
24      * zero_point = (min_error < max_error) ? zero_point_min : zero_point_max
25      */
26 }
```

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```

27 // See
28 // https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/native/quantized/QTensor.
   ↪ cpp#L14
29 // and
30 static void TestQuantizePerTensorDynamic() {
31     torch::Tensor r = torch::tensor({-1, 0, 2}, torch::kFloat32);
32     torch::Tensor q = torch::quantize_per_tensor_dynamic(r, torch::kQInt8, false);
33     std::cout << "q: " << q << "\n";
34     #if 0
35     q: -1
36         0
37         2
38     [ QuantizedCPUQInt8Type{3}, qscheme: per_tensor_affine, scale: 0.0117647, zero_point: -
   ↪ 43 ]
39     #endif
40     std::cout << "q.int_repr(): " << q.int_repr() << "\n";
41     #if 0
42     q.int_repr(): -128
43         -43
44         127
45     [ CPUCharType{3} ]
46     #endif
47 }
48
49 int main() {
50     TestChooseQuantizationParams();
51     TestQuantizePerTensorDynamic();
52     return 0;
53 }

```

## 8.7.4 torch.quantize\_per\_channel

See [https://pytorch.org/docs/stable/generated/torch.quantize\\_per\\_channel.html#torch.quantize\\_per\\_channel](https://pytorch.org/docs/stable/generated/torch.quantize_per_channel.html#torch.quantize_per_channel) `\_k`

```

def test_quantize_per_channel_2d():
    # (N, C)
    a = torch.tensor(
        [
            [1, 2, 3],
            [4, 5, 6],
        ],
        dtype=torch.float32,
    )
    assert a.shape == (2, 3)
    scales = torch.tensor([0.125, 0.25, 0.5])

    # It will be converted to torch.int64 internally
    zero_points = torch.tensor([10, 20, 30], dtype=torch.int32)
    q = torch.quantize_per_channel(
        input=a,
        scales=scales,

```

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```

        zero_points=zero_points,
        axis=1,
        dtype=torch.qint8,
    )
    assert q.dtype == torch.qint8

    assert q.q_per_channel_scales().dtype == torch.float64
    assert torch.all(torch.eq(q.q_per_channel_scales(), scales))

    assert q.q_per_channel_zero_points().dtype == torch.int64
    assert torch.all(torch.eq(q.q_per_channel_zero_points(), zero_points))

    assert str(q.qscheme()) == "torch.per_channel_affine"

    assert q.q_per_channel_axis() == 1

    i = q.int_repr()
    expected_i = torch.tensor([[18, 28, 36], [42, 40, 42]], dtype=torch.int8)
    assert i.dtype == torch.int8
    assert torch.all(torch.eq(i, expected_i))

    assert i[0][0].item() == a[0][0].item() / scales[0] + zero_points[0]
    assert i[0][1].item() == a[0][1].item() / scales[1] + zero_points[1]
    assert i[0][2].item() == a[0][2].item() / scales[2] + zero_points[2]

    assert i[1][0].item() == a[1][0].item() / scales[0] + zero_points[0]
    assert i[1][1].item() == a[1][1].item() / scales[1] + zero_points[1]
    assert i[1][2].item() == a[1][2].item() / scales[2] + zero_points[2]

    d = q.dequantize()
    assert torch.all(torch.eq(d, a))

    f = torch.dequantize(q)
    assert torch.all(torch.eq(f, a))

    # print(q)
    """
    tensor([[1., 2., 3.],
           [4., 5., 6.]], size=(2, 3), dtype=torch.qint8,
           quantization_scheme=torch.per_channel_affine,
           scale=tensor([0.1250, 0.2500, 0.5000], dtype=torch.float64),
           zero_point=tensor([10, 20, 30]), axis=1)
    """

```

## 8.7.5 Observer

Listing 58: ./code/observer/ex0.py

```
1  #!/usr/bin/env python3
2
3  import torch
4  from torch.ao.quantization.observer import _with_args, MinMaxObserver
5
6
7  class Foo:
8      def __init__(self, a=1, b=2):
9          self.a = a
10         self.b = b
11
12
13  def test_with_args():
14      Foo.with_args = classmethod(_with_args)
15      foo_builder = Foo.with_args(a=3).with_args(b=4).with_args(a=10)
16      f = foo_builder()
17      assert f.a == 10 # the last a=10 replaces the first a=3
18      assert f.b == 4
19
20      f2 = foo_builder()
21      assert id(f) != id(f2)
22
23
24  def test_min_max_observer():
25      ob = MinMaxObserver(dtype=torch.qint8)
26      print(ob) # MinMaxObserver(min_val=-inf, max_val=-inf)
27
28      ob(torch.tensor([1, 2, 3]))
29      print(ob) # MinMaxObserver(min_val=1.0, max_val=3.0)
30
31      ob(torch.tensor([-1, 30]))
32      print(ob) # MinMaxObserver(min_val=-1.0, max_val=30.0)
33      scale, zero_point = ob.calculate_qparams()
34      print("scale", scale) # scale tensor([0.1216])
35      print("zero_point", zero_point) # zero_point tensor([-120], dtype=torch.int32)
36
37
38  def main():
39      test_with_args()
40      test_min_max_observer()
41
42
43  if __name__ == "__main__":
44      main()
```

## 8.7.6 Hello

Listing 59: ./code/ex1.py

```

1  #!/usr/bin/env python3
2
3  import torch
4  import torch.nn as nn
5
6
7  class Model(torch.nn.Module):
8      def __init__(self):
9          super().__init__()
10         self.fc = nn.Linear(1, 1)
11
12     def forward(self, x):
13         x = self.fc(x)
14         return x
15
16
17 def main():
18     m = Model()
19     model_int8 = torch.quantization.quantize_dynamic(
20         model=m,
21         qconfig_spec={torch.nn.Linear},
22         dtype=torch.qint8,
23     )
24     print(model_int8)
25     print(model_int8.fc)
26     assert model_int8.fc.weight().is_quantized
27     assert model_int8.fc.weight().dtype == torch.qint8
28
29     assert model_int8.fc.bias().is_quantized is False
30     assert model_int8.fc.bias().dtype == torch.float32
31     assert isinstance(model_int8.fc, torch.nn.quantized.dynamic.Linear)
32     print(type(model_int8.fc))
33
34     x = torch.tensor([[1.0]], dtype=torch.float32)
35     y = m(x)
36     print(x, y)  # tensor([[1.]]) tensor([[ -1.2900]], grad_fn=<AddmmBackward0>)
37
38     qy = model_int8(x)
39     print(qy)  # tensor([[ -1.2931]])
40
41
42 if __name__ == "__main__":
43     torch.manual_seed(20220723)
44     main()

```

## 8.7.7 References

The main implementation is in

<https://github.com/pytorch/pytorch/tree/master/aten/src/ATen/native/quantized>

- Introducing Quantized Tensor  
<https://github.com/pytorch/pytorch/wiki/Introducing-Quantized-Tensor>
- Model Quantization for PyTorch (Proposal) #18318  
<https://github.com/pytorch/pytorch/issues/18318>
- torch\_quantization\_design\_proposal  
[https://github.com/pytorch/pytorch/wiki/torch\\_quantization\\_design\\_proposal](https://github.com/pytorch/pytorch/wiki/torch_quantization_design_proposal)

## Links

- [https://github.com/pytorch/pytorch/blob/master/test/quantization/core/test\\_quantized\\_tensor.py](https://github.com/pytorch/pytorch/blob/master/test/quantization/core/test_quantized_tensor.py)
- [https://github.com/pytorch/pytorch/blob/master/test/quantization/core/experimental/test\\_quantized\\_tensor.py](https://github.com/pytorch/pytorch/blob/master/test/quantization/core/experimental/test_quantized_tensor.py)
- [https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/test/quantized\\_test.cpp](https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/test/quantized_test.cpp)
- <https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/native/quantized/README.md>
- <https://pytorch.org/blog/introduction-to-quantization-on-pytorch/>
- <https://pytorch.org/docs/stable/quantization.html>
- Deep Dive on PyTorch Quantization - Chris Gottbrath  
YouTube: <https://www.youtube.com/watch?v=c3MT2qV5f9w>

## 8.8 android

### 8.8.1 References

- <https://zhuanlan.zhihu.com/p/54665674>
- Pytorch model to Caffe & ncnn  
<https://github.com/starimeL/PytorchConverter>

## 8.9 onnx

### 8.9.1 Install

```
pip install onnx onnxruntime
pip install netron # for visualization
# Or go to https://netron.app/
```

## API references

- <https://github.com/onnx/onnx/blob/main/docs/PythonAPIOverview.md>
- [https://onnxruntime.ai/docs/api/python/api\\_summary.html#inferencesession](https://onnxruntime.ai/docs/api/python/api_summary.html#inferencesession)

### 8.9.2 Hello

Listing 60: ./code/hello/ex0.py

```

1  #!/usr/bin/env python3
2
3  import torch
4  import torch.nn as nn
5
6
7  class Foo(nn.Module):
8      def __init__(self, i):
9          super().__init__()
10         self.relu = nn.ReLU()
11         self.i = 1
12
13     def forward(self, x):
14         if x.sum().item() > 0:
15             return self.relu(x + 1)
16         else:
17             return self.relu(x + 2)
18
19
20 def main():
21     f = Foo(1)
22     f.eval() # f.train(False)
23     f = torch.jit.script(f)
24
25     x = torch.rand(2, 3, 4)
26     # [N, T, C]
27     torch.onnx.export(
28         f,
29         x,
30         "f.onnx",
31         verbose=False,
32         input_names=["x"],
33         output_names=["y"],
34         dynamic_axes={"x": {0: "batch_size", 1: "T"}, "y": [0, 1]},
35         # dynamic_axes={"x": [0, 1], "y": [0, 1]},
36     )
37
38
39 if __name__ == "__main__":
40     main()

```

Listing 61: ./code/hello/ex0-1.py

```
1  #!/usr/bin/env python3
2
3  import onnx
4
5
6  def main():
7      model = onnx.load("f.onnx")
8      # print(model)
9      # Check that the model is well formed
10     onnx.checker.check_model(model)
11     # Print a human readable representation of the graph
12     print(onnx.helper.printable_graph(model.graph))
13     onnx.save(model, "f2.onnx")
14
15
16 if __name__ == "__main__":
17     main()
```

Listing 62: ./code/hello/ex0-2.py

```
1  #!/usr/bin/env python3
2
3  import onnxruntime as ort
4  import numpy as np
5
6
7  def main():
8      # https://github.com/microsoft/onnxruntime/issues/10113
9      options = ort.SessionOptions()
10     options.inter_op_num_threads = 1
11     options.intra_op_num_threads = 1
12
13     ort_session = ort.InferenceSession("f.onnx", sess_options=options)
14
15     x = np.arange(24).reshape(2, 3, 4).astype(np.float32)
16     ortvalue = ort.OrtValue.ortvalue_from_numpy(x)
17     assert ortvalue.device_name() == "cpu"
18     assert list(ortvalue.shape()) == list(x.shape)
19     assert ortvalue.data_type() == "tensor(float)"
20     assert ortvalue.is_tensor() is True
21
22     results = ort_session.run(["y"], {"x": ortvalue})
23     print(results)
24
25     ort_inputs = {ort_session.get_inputs()[0].name: x}
26     results = ort_session.run(["y"], ort_inputs)
27     print(results)
28
29     results = ort_session.run(["y"], {"x": x})
30     print(results)
```

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```

31
32 # https://onnxruntime.ai/docs/api/python/api_summary.html#onnxruntime.NodeArg
33 inputs = ort_session.get_inputs()
34 assert isinstance(inputs, list)
35 assert len(inputs) == 1
36 assert isinstance(inputs[0], ort.NodeArg)
37 print(inputs[0].name, inputs[0].type, inputs[0].shape)
38 assert inputs[0].name == "x"
39 assert inputs[0].type == "tensor(float)"
40 assert inputs[0].shape == ["batch_size", "T", 4]
41
42 outputs = ort_session.get_outputs()
43 assert isinstance(outputs, list)
44 assert isinstance(outputs[0], ort.NodeArg)
45 assert len(outputs) == 1
46 assert outputs[0].name == "y"
47 assert outputs[0].type == "tensor(float)"
48 assert outputs[0].shape == ["y_dynamic_axes_1", "y_dynamic_axes_2", 4]
49
50
51 if __name__ == "__main__":
52     main()

```

## 8.9.3 Multiple models

Listing 63: ./code/multiple-models/ex.py

```

1  #!/usr/bin/env python3
2
3  import torch
4  import torch.nn as nn
5  import onnx
6  import onnxruntime as ort
7  import numpy as np
8  import os
9
10
11 class Foo(nn.Module):
12     def forward(self, x):
13         return x + 1
14
15
16 class Bar(nn.Module):
17     def forward(self, x):
18         return x - 1
19
20
21 def export_to_onnx():
22     x = torch.rand(2, 3, dtype=torch.float32)
23     f = Foo()

```

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```

24 torch.onnx.export(
25     f,
26     x,
27     "f.onnx",
28     verbose=False,
29     input_names=["x1"],
30     output_names=["y1"],
31     dynamic_axes={
32         "x1": {0: "N", 1: "T"},
33         "y1": {0: "N", 1: "T"},
34     },
35 )

```

```

36
37 x = torch.rand(1, dtype=torch.float32)
38 b = Bar()
39 torch.onnx.export(
40     b,
41     x,
42     "b.onnx",
43     verbose=False,
44     input_names=["x2"],
45     output_names=["y2"],
46     dynamic_axes={
47         "x2": {0: "N"},
48         "y2": {0: "N"},
49     },
50 )

```

```

51
52
53 def merge_models():
54     f = onnx.load("f.onnx")
55     f = onnx.compose.add_prefix(f, prefix="f/")
56     b = onnx.load("b.onnx")
57     combined_model = onnx.compose.merge_models(f, b, io_map={})
58     onnx.save(combined_model, "all.onnx")

```

```

59
60
61 def test_merged_model():
62     # https://github.com/microsoft/onnxruntime/issues/10113
63     options = ort.SessionOptions()
64     options.inter_op_num_threads = 1
65     options.intra_op_num_threads = 1
66
67     all_model = onnx.load("all.onnx")
68
69     extractor = onnx.utils.Extractor(all_model)
70
71     f = extractor.extract_model(input_names=["f/x1"], output_names=["f/y1"])
72     f_session = ort.InferenceSession(f.SerializeToString(), sess_options=options)
73     f_inputs = f_session.get_inputs()
74     f_out = f_session.run(["f/y1"], {"f/x1": np.array([[1, 3]], dtype=np.float32)})
75     print(f_out[0]) # [[2. 4.]]

```

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```

76     b = extractor.extract_model(input_names=["x2"], output_names=["y2"])
77     b_session = ort.InferenceSession(b.SerializeToString(), sess_options=options)
78     b_inputs = b_session.get_inputs()
79     b_out = b_session.run(["y2"], {"x2": np.array([1, 3], dtype=np.float32)})
80     print(b_out[0]) # [0. 2.]
81
82
83
84 def main():
85     export_to_onnx()
86     merge_models()
87     test_merged_model()
88     os.remove("f.onnx")
89     os.remove("b.onnx")
90     os.remove("all.onnx")
91
92
93 if __name__ == "__main__":
94     main()

```

We can first merge multiple models into one and then extract them.

### 8.9.4 References

- (OPTIONAL) EXPORTING A MODEL FROM PYTORCH TO ONNX AND RUNNING IT USING ONNX RUNTIME  
[https://pytorch.org/tutorials/advanced/super\\_resolution\\_with\\_onnxruntime.html](https://pytorch.org/tutorials/advanced/super_resolution_with_onnxruntime.html)
- Dynamic dummy input when exporting a PyTorch model? #654  
<https://github.com/onnx/onnx/issues/654>
- onnxruntime latest version segment fault #10113  
<https://github.com/microsoft/onnxruntime/issues/10113>

## 8.10 nn.LSTM

See <https://pytorch.org/docs/stable/generated/torch.nn.LSTM.html>

Listing 64: ./code/lstm-test.py

```

1  #!/usr/bin/env python3
2
3  import torch
4  import torch.nn as nn
5
6
7  """
8  self.lstm = LSTM(
9      input_size=2,

```

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```

10     hidden_size=5,
11     num_layers=1,
12     bias=True,
13     proj_size=2,
14 )
15
16 lstm.weight_ih_l0 [20, 2]
17 lstm.weight_hh_l0 [20, 2]
18 lstm.bias_ih_l0 [20]
19 lstm.bias_hh_l0 [20]
20 lstm.weight_hr_l0 [2, 5]
21 """
22
23
24 class Foo(nn.Module):
25     def __init__(self):
26         super().__init__()
27         self.lstm = nn.LSTM(
28             input_size=3,
29             hidden_size=5,
30             num_layers=1,
31             bias=True,
32             proj_size=4,
33         )
34
35     def forward(self, x, h0, c0):
36         """
37         Args:
38             x:
39                 (T, N, H_in), H_in is input dimension of x
40             h0:
41                 (num_layers, N, H_out), H_out is proj_size
42             c0:
43                 (num_layers, N, H_cell), H_cell is hidden_dim
44         """
45         y, (hx, cx) = self.lstm(x, (h0, c0))
46         return y, hx, cx
47
48
49 @torch.no_grad()
50 def main():
51     f = Foo()
52     dim_in = 3
53     dim_proj = 4
54     dim_hidden = 5
55     x = torch.rand(1, 1, dim_in)
56     h0 = torch.rand(1, 1, dim_proj)
57     c0 = torch.rand(1, 1, dim_hidden)
58     y, hx, cx = f(x, h0, c0)
59
60     w_ih = f.state_dict()["lstm.weight_ih_l0"]
61     w_hh = f.state_dict()["lstm.weight_hh_l0"]

```

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```

62
63     b_ih = f.state_dict()["lstm.bias_ih_l0"]
64     b_hh = f.state_dict()["lstm.bias_hh_l0"]
65
66     w_hr = f.state_dict()["lstm.weight_hr_l0"]
67
68     w_ii, w_if, w_ig, w_io = w_ih.split(5, dim=0)
69     w_hi, w_hf, w_hg, w_ho = w_hh.split(5, dim=0)
70
71     b_ii, b_if, b_ig, b_io = b_ih.split(5, dim=0)
72     b_hi, b_hf, b_hg, b_ho = b_hh.split(5, dim=0)
73
74     print(y, hx, cx)
75     print(y.shape)
76     print(hx.shape)
77     print(cx.shape)
78
79     i_gate = (x @ w_ii.t() + b_ii + h0 @ w_hi.t() + b_hi).sigmoid()
80     f_gate = (x @ w_if.t() + b_if + h0 @ w_hf.t() + b_hf).sigmoid()
81     g_gate = (x @ w_ig.t() + b_ig + h0 @ w_hg.t() + b_hg).tanh()
82     o_gate = (x @ w_io.t() + b_io + h0 @ w_ho.t() + b_ho).sigmoid()
83     c = f_gate * c0 + i_gate * g_gate
84
85     h = o_gate * c.tanh()
86     h = h @ w_hr.t()
87
88     print(h, h, c)
89
90
91 if __name__ == "__main__":
92     torch.manual_seed(20220903)
93     main()

```



## 9.1 asyncio

### 9.1.1 asyncio.Future

### 9.1.2 iterator

See <https://peps.python.org/pep-0234/>

### 9.1.3 yield

### 9.1.4 Hello World

#### Exercise 1

Listing 1: ./code/hello\_world/ex1.py

```
1 import asyncio
2
3
4 async def hello():
5     print("hello world")
6
7
8 asyncio.run(hello())
```

#### Exercise 2

Listing 2: ./code/hello\_world/ex2.py

```
1 import asyncio
2 import time
3
4
5 loop = asyncio.get_event_loop()
6
7
```

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```
8 @asyncio.coroutine
9 def hello():
10     print(f"hello {time.strftime('%X')}")
11     yield from asyncio.sleep(1)
12     print(f"world {time.strftime('%X')}")
13
14
15 if __name__ == "__main__":
16     loop.run_until_complete(hello())
```

## 9.1.5 References

- PEP 234 – Iterators  
<https://peps.python.org/pep-0234/>
- Why does defining `__getitem__` on a class make it iterable in python?  
<https://localcoder.org/why-does-defining-getitem-on-a-class-make-it-iterable-in-python>
- PEP 255 – Simple Generators  
<https://peps.python.org/pep-0255/>
- Curious Course on Coroutines and Concurrency  
[https://www.youtube.com/watch?v=Z\\_OAllhXziw&ab\\_channel=DavidBeazley](https://www.youtube.com/watch?v=Z_OAllhXziw&ab_channel=DavidBeazley)  
By David Beazley.
- Generator Tricks for Systems Programmers  
<https://www.dabeaz.com/generators2/>
- Generators: The Final Frontier  
<[https://www.youtube.com/watch?v=5-qadlG7tWo&ab\\_channel=DavidBeazley](https://www.youtube.com/watch?v=5-qadlG7tWo&ab_channel=DavidBeazley)>  
By David Beazley.

## 9.1.6 TODOs

`asyncio.to_thread()` runs the function in an executor, where the default executor is a threadpool executor, which invokes `loop.run_in_executor()` indirectly.

How to set the executor of a loop? Maybe something related to `set_default_executor`?

If we want to schedule a callback to run in the loop from the C++ code, we can use `loop.call_soon_safe()` method.



## 9.2 argv

From the doc <https://docs.python.org/3/library/sys.html>:

The `list` of command line arguments passed to a Python script. `argv[0]` **is** the script name (it **is** operating system dependent whether this **is** a full pathname **or not**). If the command was executed using the `-c` command line option to the interpreter, `argv[0]` **is set** to the string `'-c'`. If no script name was passed to the Python interpreter, `argv[0]` **is** the empty string.

Note that `argv` is at least of size 1, though `argv[0]` may be an empty string.

```
import sys
print(sys.argv)
```

## 9.3 TODO

Python with zeroMQ (c extension)

## 9.4 time

```
import time
print(f'Started at {time.strftime("%X")}')
# do something
print(f'Finished at {time.strftime("%X")}')
```

## 9.5 Numbers

### 9.5.1 binary representation

Listing 3: `./code/numbers/representations.py`

```
1 print(bin(1)) # 0b1
2 print(bin(3)) # 0b11
3 print(bin(255)) # 0b11111111
4 print(bin(256)) # 0b1000000000
5 assert isinstance(bin(1), str)
6 assert int("11", base=2) == 3
7 assert int("0b11", base=0) == 3
8 assert hex(2) == "0x2"
9 assert hex(10) == "0xa"
10
11 assert oct(10) == "0o12"
12 assert int("12", base=8) == 10
13 assert int("0o12", base=0) == 10
```

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```
14
15 assert 1_000 == 1000
16 assert 1_000_000 == 1000000
```

## 9.6 str

### 9.6.1 format

See <https://docs.python.org/3/library/string.html#formatspec> and <https://peps.python.org/pep-3101/>

Listing 4: ./code/str/format.py

```
1 a = 1
2 b = 2
3 c = 3
4 assert "{}".format(a) == "1"
5 assert "{}".format(b) == "2"
6 assert "{0} {1} {foo}".format(a, b, foo=c) == "1 2 3"
7
8 # 1 - the first positional argument (counting from 0)
9 # foo - it is a keyword argument
10 # 0 - the zeros positional
11 assert "{1} {foo} {0}".format(a, b, foo=c) == "2 3 1"
12
13 assert "{0} {1} {0} {0}".format(a, b) == "1 2 1 1"
14
15 assert "skip braces {0} {}".format(a) == "skip braces 1 {}"
16 print("{}") # {}
17 try:
18     print("{} {}".format(a))
19 except IndexError as e:
20     assert str(e) == "Replacement index 1 out of range for positional args tuple"
21
22 assert "{0:2}".format(a) == " 1"
23 assert "{0:02}".format(a) == "01"
24 assert "{0:03}".format(a) == "001"
25 assert "{0:1}".format(-1) == "-1"
26 assert "{0:2}".format(-1) == "-1"
27 assert "{0:3}".format(-1) == "-1"
28 assert "{0:03}".format(-1) == "-01"
29
30 assert "{0:.2f}".format(0.5) == "0.50"
31 assert "{0:.3f}".format(0.5) == "0.500"
```

## 9.7 enum

### 9.7.1 Hello

See <https://docs.python.org/3.11/howto/enum.html>

#### Enum

Note:

- It is iterable, i.e., supports `__iter__`
- name and value
- alias and `@unique`.
- `__members__`.
- `str` and `repr`.
- `auto`

Listing 5: `./code/hello/ex1.py`

```

1  from enum import Enum
2
3
4  class Color(Enum):
5      RED = 1
6      GREEN = 2
7      BLUE = 3
8      # BLUE = 4 # TypeError: Attempted to reuse key: 'BLUE'
9      ALIAS_FOR_RED = 1 # Use @unique to disallow this
10     MAX_COLOR = 4 # Note the naming convention
11
12
13  assert isinstance(Color.RED, Color)
14
15  assert str(Color(1)) == "Color.RED"
16  assert str(repr(Color(1))) == "<Color.RED: 1>"
17
18  assert Color.RED.name == "RED"
19  assert Color.BLUE.value == 3
20
21  print(list(Color))
22  print(type(list(Color)[0]))
23  for c in Color:
24      print(c, type(c))
25
26  """
27  [<Color.RED: 1>, <Color.GREEN: 2>, <Color.BLUE: 3>, <Color.MAX_COLOR: 4>]
28  <enum 'Color'>
29  Color.RED <enum 'Color'>
30  Color.GREEN <enum 'Color'>
31  Color.BLUE <enum 'Color'>

```

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```

32 Color.MAX_COLOR <enum 'Color'>
33 """
34
35 assert Color(1) == Color.RED
36 assert Color["RED"] == Color.RED
37 assert Color["ALIAS_FOR_RED"] == Color.RED
38
39 print(Color.__members__)
40 """
41 {'RED': <Color.RED: 1>, 'GREEN': <Color.GREEN: 2>, 'BLUE': <Color.BLUE: 3>, 'ALIAS_FOR_RED':
42  ↳<Color.RED: 1>, 'MAX_COLOR': <Color.MAX_COLOR: 4>}
"""

```

## Flag

Listing 6: ./code/hello/ex2.py

```

1  from enum import Flag
2
3
4  class Weekday(Flag):
5      MONDAY = 1 << 0
6      TUESDAY = 1 << 1
7      WEDNESDAY = 1 << 2
8      THURSDAY = 1 << 3
9      FRIDAY = 1 << 4
10     SATURDAY = 1 << 5
11     SUNDAY = 1 << 6
12
13
14     assert Weekday.MONDAY.value == 1
15     assert Weekday.TUESDAY.value == 2
16     assert Weekday.WEDNESDAY.value == 4
17     assert Weekday.THURSDAY.value == 8
18     assert Weekday.FRIDAY.value == 16
19     assert Weekday.SATURDAY.value == 32
20     assert Weekday.SUNDAY.value == 64
21
22     weekend = Weekday.SATURDAY | Weekday.SUNDAY
23     print(weekend) # Weekday.SUNDAY|SATURDAY
24     print(repr(weekend)) # <Weekday.SUNDAY|SATURDAY: 96>
25     assert Weekday.SATURDAY in weekend
26     assert Weekday.SUNDAY in weekend
27     assert Weekday.MONDAY not in weekend

```

## auto

Listing 7: ./code/hello/ex3.py

```
1 from enum import Enum, Flag, auto
2
3
4 class Weekday(Flag):
5     MONDAY = auto() # start from 1
6     TUESDAY = auto()
7     WEDNESDAY = auto()
8     THURSDAY = auto()
9     FRIDAY = auto()
10    SATURDAY = 128
11    SUNDAY = auto()
12
13
14 assert Weekday.MONDAY.value == 1
15 assert Weekday.TUESDAY.value == 2
16 assert Weekday.WEDNESDAY.value == 4
17 assert Weekday.THURSDAY.value == 8
18 assert Weekday.FRIDAY.value == 16
19 assert Weekday.SATURDAY.value == 128
20 assert Weekday.SUNDAY.value == 256
21
22
23 class Color(Enum):
24     RED = auto() # start from 1
25     GREEN = auto()
26     BLUE = auto()
27     YELLOW = 10
28     WHITE = auto()
29
30
31 assert Color.RED.value == 1
32 assert Color.GREEN.value == 2
33 assert Color.BLUE.value == 3
34 assert Color.YELLOW.value == 10
35 assert Color.WHITE.value == 11
```

## 9.8 socket

### 9.8.1 AddressFamily

It is an IntEnum and all of its members are exported to socket.

Listing 8: ./code/address-family.py

```
1 import socket
2
3 print(list(socket.AddressFamily))
```

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```

4  """
5  [<AddressFamily.AF_UNSPEC: 0>, <AddressFamily.AF_UNIX: 1>,
6  <AddressFamily.AF_INET: 2>, <AddressFamily.AF_AX25: 3>,
7  <AddressFamily.AF_IPX: 4>, <AddressFamily.AF_APPLETALK: 5>,
8  <AddressFamily.AF_NETROM: 6>, <AddressFamily.AF_BRIDGE: 7>,
9  <AddressFamily.AF_ATMPVC: 8>, <AddressFamily.AF_X25: 9>,
10 <AddressFamily.AF_INET6: 10>, <AddressFamily.AF_ROSE: 11>,
11 <AddressFamily.AF_NETBEUI: 13>, <AddressFamily.AF_SECURITY: 14>,
12 <AddressFamily.AF_KEY: 15>, <AddressFamily.AF_NETLINK: 16>,
13 <AddressFamily.AF_PACKET: 17>, <AddressFamily.AF_ASH: 18>,
14 <AddressFamily.AF_ECONET: 19>, <AddressFamily.AF_ATMSVC: 20>,
15 <AddressFamily.AF_RDS: 21>, <AddressFamily.AF_SNA: 22>,
16 <AddressFamily.AF_IRDA: 23>, <AddressFamily.AF_PPPOX: 24>,
17 <AddressFamily.AF_WANPIPE: 25>, <AddressFamily.AF_LLC: 26>,
18 <AddressFamily.AF_CAN: 29>, <AddressFamily.AF_TIPC: 30>,
19 <AddressFamily.AF_BLUETOOTH: 31>, <AddressFamily.AF_ALG: 38>,
20 <AddressFamily.AF_VSOCK: 40>, <AddressFamily.AF_QIPCRTR: 42>]
21 """
22
23 assert socket.AF_UNIX == socket.AddressFamily.AF_UNIX
24 assert socket.AF_INET == socket.AddressFamily.AF_INET

```

## 9.8.2 SocketKind

It is an `IntEnum` and all of its members are exported to `socket`.

Listing 9: `./code/socket-kind.py`

```

1  import socket
2
3  print(list(socket.SocketKind))
4  """
5  [<SocketKind.SOCK_STREAM: 1>, <SocketKind.SOCK_DGRAM: 2>,
6  <SocketKind.SOCK_RAW: 3>, <SocketKind.SOCK_RDM: 4>,
7  <SocketKind.SOCK_SEQPACKET: 5>, <SocketKind.SOCK_NONBLOCK: 2048>,
8  <SocketKind.SOCK_CLOEXEC: 524288>]
9  """
10
11 assert socket.SOCK_STREAM == socket.SocketKind.SOCK_STREAM
12 assert socket.SOCK_DGRAM == socket.SocketKind.SOCK_DGRAM

```

### 9.8.3 struct sockaddr\_in

#### See also

- [https://www.gta.ufrj.br/ensino/eel878/sockets/sockaddr\\_inman.html](https://www.gta.ufrj.br/ensino/eel878/sockets/sockaddr_inman.html)
- <https://man7.org/linux/man-pages/man7/ip.7.html>

Listing 10: ./code/sockaddr\_in.h

```

1 // https://github.com/lattera/glibc/blob/master/bits/sockaddr.h
2 /* POSIX.1g specifies this type name for the 'sa_family' member. */
3 typedef unsigned short int sa_family_t;
4
5 #define __SOCKADDR_COMMON(sa_prefix) sa_family_t sa_prefix##family
6
7 // https://github.com/lattera/glibc/blob/master/bits/socket.h
8
9 struct sockaddr {
10     __SOCKADDR_COMMON(sa_); /* Common data: address family and length. */
11     char sa_data[14]; /* Address data. */
12 };
13
14 // https://github.com/lattera/glibc/blob/master/inet/netinet/in.h
15 struct sockaddr_in {
16     __SOCKADDR_COMMON(sin_);
17     in_port_t sin_port; /* Port number. */
18     struct in_addr sin_addr; /* Internet address. */
19
20     /* Pad to size of 'struct sockaddr'. */
21     unsigned char sin_zero[sizeof(struct sockaddr) - __SOCKADDR_COMMON_SIZE -
22                               sizeof(in_port_t) - sizeof(struct in_addr)];
23 };
24
25 typedef uint32_t in_addr_t;
26 struct in_addr {
27     in_addr_t s_addr;
28 };
29
30 /* Address to accept any incoming messages. */
31 #define INADDR_ANY ((in_addr_t)0x00000000)
32 /* Address to send to all hosts. */
33 #define INADDR_BROADCAST ((in_addr_t)0xffffffff)
34 /* Address indicating an error return. */
35 #define INADDR_NONE ((in_addr_t)0xffffffff)
36
37 /* Network number for local host loopback. */
38 #define IN_LOOPBACKNET 127
39 /* Address to loopback in software to local host. */
40 #ifndef INADDR_LOOPBACK
41 #define INADDR_LOOPBACK ((in_addr_t)0x7f000001) /* Inet 127.0.0.1. */
42 #endif

```

## 9.8.4 AddressInfo

Listing 11: ./code/address-info.py

```

1 import socket
2
3 print(list(socket.AddressInfo))
4 """
5 [<AddressInfo.AI_PASSIVE: 1>, <AddressInfo.AI_CANONNAME: 2>,
6 <AddressInfo.AI_NUMERICHOST: 4>, <AddressInfo.AI_V4MAPPED: 8>,
7 <AddressInfo.AI_ALL: 16>, <AddressInfo.AI_ADDRCONFIG: 32>,
8 <AddressInfo.AI_NUMERICSERV: 1024>]
9 """
10 assert socket.AI_PASSIVE == socket.AddressInfo.AI_PASSIVE

```

## 9.8.5 inet\_pton

[https://man7.org/linux/man-pages/man3/inet\\_pton.3.html](https://man7.org/linux/man-pages/man3/inet_pton.3.html)

Representation format to network address.

The resulting network address is in network order, i.e., big endian.

Listing 12: ./code/inet\_pton.c

```

1 #include <arpa/inet.h>
2 #include <stdio.h>
3
4 int main() {
5     struct in_addr addr;
6     int res = inet_pton(AF_INET, "192.168.1.2", &addr);
7     printf("%08x\n", addr.s_addr);
8     printf("192: %x\n", 192);
9     printf("168: %x\n", 168);
10    printf("1: %x\n", 1);
11    printf("2: %x\n", 2);
12    return 0;
13 }
14 #if 0
15 ./inet_pton
16 0201a8c0
17 192: c0
18 168: a8
19 1: 1
20 2: 2
21 #endif

```

Its implementation can be found at [https://github.com/bminor/glibc/blob/master/resolv/inet\\_pton.c](https://github.com/bminor/glibc/blob/master/resolv/inet_pton.c)

Listing 13: ./code/inet\_pton\_impl.c

```

1 // See https://github.com/bminor/glibc/blob/master/resolv/inet_pton.c
2 //

```

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```

3  /* Copyright (C) 1996-2022 Free Software Foundation, Inc.
4     This file is part of the GNU C Library.
5
6     The GNU C Library is free software; you can redistribute it and/or
7     modify it under the terms of the GNU Lesser General Public
8     License as published by the Free Software Foundation; either
9     version 2.1 of the License, or (at your option) any later version.
10
11    The GNU C Library is distributed in the hope that it will be useful,
12    but WITHOUT ANY WARRANTY; without even the implied warranty of
13    MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU
14    Lesser General Public License for more details.
15
16    You should have received a copy of the GNU Lesser General Public
17    License along with the GNU C Library; if not, see
18    <https://www.gnu.org/licenses/>.  */
19
20 /*
21  * Copyright (c) 1996,1999 by Internet Software Consortium.
22  *
23  * Permission to use, copy, modify, and distribute this software for any
24  * purpose with or without fee is hereby granted, provided that the above
25  * copyright notice and this permission notice appear in all copies.
26  *
27  * THE SOFTWARE IS PROVIDED "AS IS" AND INTERNET SOFTWARE CONSORTIUM DISCLAIMS
28  * ALL WARRANTIES WITH REGARD TO THIS SOFTWARE INCLUDING ALL IMPLIED WARRANTIES
29  * OF MERCHANTABILITY AND FITNESS.  IN NO EVENT SHALL INTERNET SOFTWARE
30  * CONSORTIUM BE LIABLE FOR ANY SPECIAL, DIRECT, INDIRECT, OR CONSEQUENTIAL
31  * DAMAGES OR ANY DAMAGES WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR
32  * PROFITS, WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS
33  * ACTION, ARISING OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THIS
34  * SOFTWARE.
35  */
36
37 #include <arpa/inet.h>
38 #include <arpa/nameser.h>
39 #include <ctype.h>
40 #include <errno.h>
41 #include <netinet/in.h>
42 #include <resolv/resolv-internal.h>
43 #include <string.h>
44 #include <sys/socket.h>
45 #include <sys/types.h>
46
47 static int inet_pton4 (const char *src, const char *src_end, u_char *dst);
48 static int inet_pton6 (const char *src, const char *src_end, u_char *dst);
49
50 int
51 __inet_pton_length (int af, const char *src, size_t srclen, void *dst)
52 {
53     switch (af)
54     {

```

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```

55     case AF_INET:
56         return inet_pton4 (src, src + srclen, dst);
57     case AF_INET6:
58         return inet_pton6 (src, src + srclen, dst);
59     default:
60         __set_errno (EAFNOSUPPORT);
61         return -1;
62     }
63 }
64 libc_hidden_def (__inet_pton_length)
65
66 /* Like __inet_pton_length, but use strlen (SRC) as the length of
67 SRC. */
68 int
69 __inet_pton (int af, const char *src, void *dst)
70 {
71     return __inet_pton_length (af, src, strlen (src), dst);
72 }
73 libc_hidden_def (__inet_pton)
74 weak_alias (__inet_pton, inet_pton)
75 libc_hidden_weak (inet_pton)
76
77 /* Like inet_aton but without all the hexadecimal, octal and shorthand
78 (and trailing garbage is not ignored). Return 1 if SRC is a valid
79 dotted quad, else 0. This function does not touch DST unless it's
80 returning 1.
81 Author: Paul Vixie, 1996. */
82 static int
83 inet_pton4 (const char *src, const char *end, unsigned char *dst)
84 {
85     int saw_digit, octets, ch;
86     unsigned char tmp[NS_INADDRSZ], *tp;
87
88     saw_digit = 0;
89     octets = 0;
90     *(tp = tmp) = 0;
91     while (src < end)
92     {
93         ch = *src++;
94         if (ch >= '0' && ch <= '9')
95         {
96             unsigned int new = *tp * 10 + (ch - '0');
97
98             if (saw_digit && *tp == 0)
99                 return 0;
100             if (new > 255)
101                 return 0;
102             *tp = new;
103             if (! saw_digit)
104             {
105                 if (++octets > 4)
106                     return 0;

```

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```

107         saw_digit = 1;
108     }
109 }
110 else if (ch == '.' && saw_digit)
111 {
112     if (octets == 4)
113         return 0;
114     *++tp = 0;
115     saw_digit = 0;
116 }
117 else
118     return 0;
119 }
120 if (octets < 4)
121     return 0;
122 memcpy (dst, tmp, NS_INADDRSZ);
123 return 1;
124 }
125
126 /* Return the value of CH as a hexademical digit, or -1 if it is a
127 different type of character. */
128 static int
129 hex_digit_value (char ch)
130 {
131     if ('0' <= ch && ch <= '9')
132         return ch - '0';
133     if ('a' <= ch && ch <= 'f')
134         return ch - 'a' + 10;
135     if ('A' <= ch && ch <= 'F')
136         return ch - 'A' + 10;
137     return -1;
138 }
139
140 /* Convert presentation-level IPv6 address to network order binary
141 form. Return 1 if SRC is a valid [RFC1884 2.2] address, else 0.
142 This function does not touch DST unless it's returning 1.
143 Author: Paul Vixie, 1996. Inspired by Mark Andrews. */
144 static int
145 inet_pton6 (const char *src, const char *src_endp, unsigned char *dst)
146 {
147     unsigned char tmp[NS_IN6ADDRSZ], *tp, *endp, *colonp;
148     const char *curtok;
149     int ch;
150     size_t xdigits_seen;      /* Number of hex digits since colon. */
151     unsigned int val;
152
153     tp = memset (tmp, '\\0', NS_IN6ADDRSZ);
154     endp = tp + NS_IN6ADDRSZ;
155     colonp = NULL;
156
157     /* Leading :: requires some special handling. */
158     if (src == src_endp)

```

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```

159     return 0;
160     if (*src == ':')
161     {
162         ++src;
163         if (src == src_endp || *src != ':')
164             return 0;
165     }
166
167     curtok = src;
168     xdigits_seen = 0;
169     val = 0;
170     while (src < src_endp)
171     {
172         ch = *src++;
173         int digit = hex_digit_value (ch);
174         if (digit >= 0)
175         {
176             if (xdigits_seen == 4)
177                 return 0;
178             val <= 4;
179             val |= digit;
180             if (val > 0xffff)
181                 return 0;
182             ++xdigits_seen;
183             continue;
184         }
185         if (ch == ':')
186         {
187             curtok = src;
188             if (xdigits_seen == 0)
189             {
190                 if (colonp)
191                     return 0;
192                 colonp = tp;
193                 continue;
194             }
195             else if (src == src_endp)
196                 return 0;
197             if (tp + NS_INT16SZ > endp)
198                 return 0;
199             *tp++ = (unsigned char) (val >> 8) & 0xff;
200             *tp++ = (unsigned char) val & 0xff;
201             xdigits_seen = 0;
202             val = 0;
203             continue;
204         }
205         if (ch == '.' && ((tp + NS_INADDRSZ) <= endp)
206             && inet_pton4 (curtok, src_endp, tp) > 0)
207         {
208             tp += NS_INADDRSZ;
209             xdigits_seen = 0;
210             break; /* '\0' was seen by inet_pton4. */

```

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```

211     }
212     return 0;
213 }
214 if (xdigits_seen > 0)
215 {
216     if (tp + NS_INT16SZ > endp)
217         return 0;
218     *tp++ = (unsigned char) (val >> 8) & 0xff;
219     *tp++ = (unsigned char) val & 0xff;
220 }
221 if (colonp != NULL)
222 {
223     /* Replace :: with zeros. */
224     if (tp == endp)
225         /* :: would expand to a zero-width field. */
226         return 0;
227     size_t n = tp - colonp;
228     memmove (endp - n, colonp, n);
229     memset (colonp, 0, endp - n - colonp);
230     tp = endp;
231 }
232 if (tp != endp)
233     return 0;
234 memcpy (dst, tmp, NS_IN6ADDRSZ);
235 return 1;
236 }

```

## 9.8.6 inet\_ntop

Network address to representation format.

See [https://man7.org/linux/man-pages/man3/inet\\_ntop.3.html](https://man7.org/linux/man-pages/man3/inet_ntop.3.html)

Listing 14: ./code/inet\_ntop.c

```

1  #include <arpa/inet.h>
2  #include <stdio.h>
3
4  int main() {
5      struct in_addr addr;
6      uint8_t *p = (uint8_t *)&addr.s_addr;
7      p[0] = 192;
8      p[1] = 168;
9      p[2] = 1;
10     p[3] = 2;
11     char buf[INET_ADDRSTRLEN];
12     const char *ret = inet_ntop(AF_INET, &addr.s_addr, buf, sizeof(buf));
13     printf("%s\n", buf);
14     printf("%p, %p\n", buf, ret);
15     return 0;
16 }

```

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```

17 #if 0
18 192.168.1.2
19 0x7ffc808b5e80, 0x7ffc808b5e80
20 #endif

```

Its implementation can be found at [https://github.com/bminor/glibc/blob/master/resolv/inet\\_ntop.c](https://github.com/bminor/glibc/blob/master/resolv/inet_ntop.c)

Listing 15: ./code/inet\_ntop\_impl.c

```

1 // https://github.com/bminor/glibc/blob/master/resolv/inet_ntop.c
2 /*
3  * Copyright (c) 1996-1999 by Internet Software Consortium.
4  *
5  * Permission to use, copy, modify, and distribute this software for any
6  * purpose with or without fee is hereby granted, provided that the above
7  * copyright notice and this permission notice appear in all copies.
8  *
9  * THE SOFTWARE IS PROVIDED "AS IS" AND INTERNET SOFTWARE CONSORTIUM DISCLAIMS
10 * ALL WARRANTIES WITH REGARD TO THIS SOFTWARE INCLUDING ALL IMPLIED WARRANTIES
11 * OF MERCHANTABILITY AND FITNESS. IN NO EVENT SHALL INTERNET SOFTWARE
12 * CONSORTIUM BE LIABLE FOR ANY SPECIAL, DIRECT, INDIRECT, OR CONSEQUENTIAL
13 * DAMAGES OR ANY DAMAGES WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR
14 * PROFITS, WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS
15 * ACTION, ARISING OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THIS
16 * SOFTWARE.
17 */
18
19 #include <sys/param.h>
20 #include <sys/types.h>
21 #include <sys/socket.h>
22
23 #include <netinet/in.h>
24 #include <arpa/inet.h>
25 #include <arpa/nameser.h>
26
27 #include <errno.h>
28 #include <stdio.h>
29 #include <string.h>
30
31 #ifdef SPRINTF_CHAR
32 # define SPRINTF(x) strlen(sprintf/**/x)
33 #else
34 # define SPRINTF(x) ((size_t)sprintf x)
35 #endif
36
37 /*
38  * WARNING: Don't even consider trying to compile this on a system where
39  * sizeof(int) < 4.  sizeof(int) > 4 is fine; all the world's not a VAX.
40  */
41
42 static const char *inet_ntop4 (const u_char *src, char *dst, socklen_t size);
43 static const char *inet_ntop6 (const u_char *src, char *dst, socklen_t size);

```

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```

44
45 /* char *
46  * inet_ntop(af, src, dst, size)
47  *      convert a network format address to presentation format.
48  * return:
49  *      pointer to presentation format address ('dst'), or NULL (see errno).
50  * author:
51  *      Paul Vixie, 1996.
52  */
53 const char *
54 inet_ntop (int af, const void *src, char *dst, socklen_t size)
55 {
56     switch (af) {
57     case AF_INET:
58         return (inet_ntop4(src, dst, size));
59     case AF_INET6:
60         return (inet_ntop6(src, dst, size));
61     default:
62         __set_errno (EAFNOSUPPORT);
63         return (NULL);
64     }
65     /* NOTREACHED */
66 }
67 libc_hidden_def (inet_ntop)
68
69 /* const char *
70  * inet_ntop4(src, dst, size)
71  *      format an IPv4 address
72  * return:
73  *      `dst' (as a const)
74  * notes:
75  *      (1) uses no statics
76  *      (2) takes a u_char* not an in_addr as input
77  * author:
78  *      Paul Vixie, 1996.
79  */
80 static const char *
81 inet_ntop4 (const u_char *src, char *dst, socklen_t size)
82 {
83     static const char fmt[] = "%u.%u.%u.%u";
84     char tmp[sizeof "255.255.255.255"];
85
86     if (SPRINTF((tmp, fmt, src[0], src[1], src[2], src[3])) >= size) {
87         __set_errno (ENOSPC);
88         return (NULL);
89     }
90     return strcpy(dst, tmp);
91 }
92
93 /* const char *
94  * inet_ntop6(src, dst, size)
95  *      convert IPv6 binary address into presentation (printable) format

```

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```

96  * author:
97  *      Paul Vixie, 1996.
98  */
99  static const char *
100 inet_ntop6 (const u_char *src, char *dst, socklen_t size)
101 {
102     /*
103      * Note that int32_t and int16_t need only be "at least" large enough
104      * to contain a value of the specified size.  On some systems, like
105      * Crays, there is no such thing as an integer variable with 16 bits.
106      * Keep this in mind if you think this function should have been coded
107      * to use pointer overlays.  All the world's not a VAX.
108      */
109     char tmp[sizeof "ffff:ffff:ffff:ffff:ffff:ffff:255.255.255.255"], *tp;
110     struct { int base, len; } best, cur;
111     u_int words[NS_IN6ADDRSZ / NS_INT16SZ];
112     int i;
113
114     /*
115      * Preprocess:
116      *      Copy the input (bytewise) array into a wordwise array.
117      *      Find the longest run of 0x00's in src[] for :: shorthanding.
118      */
119     memset(words, '\\0', sizeof words);
120     for (i = 0; i < NS_IN6ADDRSZ; i += 2)
121         words[i / 2] = (src[i] << 8) | src[i + 1];
122     best.base = -1;
123     cur.base = -1;
124     best.len = 0;
125     cur.len = 0;
126     for (i = 0; i < (NS_IN6ADDRSZ / NS_INT16SZ); i++) {
127         if (words[i] == 0) {
128             if (cur.base == -1)
129                 cur.base = i, cur.len = 1;
130             else
131                 cur.len++;
132         } else {
133             if (cur.base != -1) {
134                 if (best.base == -1 || cur.len > best.len)
135                     best = cur;
136                 cur.base = -1;
137             }
138         }
139     }
140     if (cur.base != -1) {
141         if (best.base == -1 || cur.len > best.len)
142             best = cur;
143     }
144     if (best.base != -1 && best.len < 2)
145         best.base = -1;
146
147     /*

```

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```

148     * Format the result.
149     */
150     tp = tmp;
151     for (i = 0; i < (NS_IN6ADDRSZ / NS_INT16SZ); i++) {
152         /* Are we inside the best run of 0x00's? */
153         if (best.base != -1 && i >= best.base &&
154             i < (best.base + best.len)) {
155             if (i == best.base)
156                 *tp++ = ':';
157             continue;
158         }
159         /* Are we following an initial run of 0x00s or any real hex? */
160         if (i != 0)
161             *tp++ = ':';
162         /* Is this address an encapsulated IPv4? */
163         if (i == 6 && best.base == 0 &&
164             (best.len == 6 || (best.len == 5 && words[5] == 0xffff))) {
165             if (!inet_ntop4(src+12, tp, sizeof tmp - (tp - tmp)))
166                 return (NULL);
167             tp += strlen(tp);
168             break;
169         }
170         tp += SPRINTF((tp, "%x", words[i]));
171     }
172     /* Was it a trailing run of 0x00's? */
173     if (best.base != -1 && (best.base + best.len) ==
174         (NS_IN6ADDRSZ / NS_INT16SZ))
175         *tp++ = ':';
176     *tp++ = '\0';
177
178     /*
179     * Check for overflow, copy, and we're done.
180     */
181     if ((socklen_t)(tp - tmp) > size) {
182         __set_errno (ENOSPC);
183         return (NULL);
184     }
185     return strcpy(dst, tmp);
186 }

```

## 9.8.7 Echo Server and Client

### Server

Listing 16: ./code/echo-hello/server.py

```

1  #!/usr/bin/env python3
2  import socket
3  import threading
4

```

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```
5 # nc localhost 6006
6
7
8 def run_server():
9     sock = socket.socket(family=socket.AF_INET, type=socket.SOCK_STREAM)
10    sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
11    sock.bind("", 6006)
12    # sock.setblocking(False) # It returns socket.BlockingIOError
13    sock.listen(2) # backlog is 2
14    while True:
15        client_sock, addr = sock.accept()
16        assert isinstance(client_sock, socket.socket)
17        assert isinstance(addr, tuple)
18        assert isinstance(addr[0], str)
19        assert isinstance(addr[1], int)
20        print("Connected from", addr) # Connected from ('127.0.0.1', 54266)
21        threading.Thread(target=handle_client, args=(client_sock,)).start()
22
23
24 def handle_client(sock: socket.socket):
25     while True:
26         data = sock.recv(1024)
27         if not data:
28             break
29         sock.sendall(data.decode("utf-8").upper().encode())
30     print("Disconnected from", sock.getpeername())
31     sock.close()
32
33
34 if __name__ == "__main__":
35     run_server()
```

To test the server, use `nc localhost 6006` or use the following client.

## Client

Listing 17: ./code/echo-hello/client.py

```

1 def main():
2     sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
3     sock.connect(("localhost", 6006))
4     for i in range(5):
5         sock.send("hello".encode())
6         b = sock.recv(1024)
7         print(b.decode())
8         time.sleep(0.5)

```

## Server2

With `concurrent.futures.ThreadPoolExecutor`.

Listing 18: ./code/echo-hello/server2.py

```

1  #!/usr/bin/env python3
2  import socket
3  import threading
4  from concurrent.futures import ThreadPoolExecutor
5
6  # nc localhost 6006
7  pool = ThreadPoolExecutor(max_workers=3)
8
9
10 def run_server():
11     sock = socket.socket(family=socket.AF_INET, type=socket.SOCK_STREAM)
12     sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
13     sock.bind("", 6006)
14     # sock.setblocking(False) # It returns socket.BlockingIOError
15     sock.listen(2) # backlog is 2
16     while True:
17         client_sock, addr = sock.accept()
18         assert isinstance(client_sock, socket.socket)
19         assert isinstance(addr, tuple)
20         assert isinstance(addr[0], str)
21         assert isinstance(addr[1], int)
22         print("Connected from", addr) # Connected from ('127.0.0.1', 54266)
23         pool.submit(handle_client, client_sock)
24
25
26 def handle_client(sock: socket.socket):
27     while True:
28         data = sock.recv(1024)
29         if not data:
30             break
31         sock.sendall(data.decode("utf-8").upper().encode())
32     print("Disconnected from", sock.getpeername())
33     sock.close()
34
35

```

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```
36 if __name__ == "__main__":  
37     run_server()
```

### 9.8.8 TODOs

- Beej's Guide to Network Programming Using Internet Sockets  
<https://www.gta.ufrj.br/ensino/eel878/sockets/index.html>
- LWN.net Weekly Edition Archives  
<https://lwn.net/Archives/>

## 10.1 Install

### 10.1.1 formatter

Install <https://github.com/google/google-java-format>

```
wget https://github.com/google/google-java-format/releases/download/v1.15.0/google-java-format-1.15.0-all-deps.jar
```

Create a script with filename `google-java-format`:

```
#!/usr/bin/env bash

java -jar /ceph-sh0/fangjun/download/google-java-format-1.15.0-all-deps.jar $@
```

`chmod +x google-java-format` and add the path to `PATH`.

### 10.1.2 JDK

Go to <https://www.oracle.com/java/technologies/downloads/#java17> and download

```
wget https://download.oracle.com/java/17/latest/jdk-17_linux-x64_bin.tar.gz
mkdir /ceph-fj/fangjun/software/
tar xvf jdk-17_linux-x64_bin.tar.gz -C /ceph-fj/fangjun/software
```

And then set the following environment variables:

```
export JAVA_HOME=/ceph-fj/fangjun/software/jdk-17.0.3
export PATH=$JAVA_HOME/bin:$JAVA_HOME
```

The source code of JDK can be download from

```
git clone https://github.com/openjdk/jdk.git
```

## 10.2 Hello world

Look at the code <https://github.com/openjdk/jdk/blob/master/src/java.base/share/classes/java/lang/System.java> to learn the coding style of java.

All primitive types, such as `int`, `char`, and `double` begin with a lowercase. All other types, such as `String` and `Math`, begin with an uppercase.

```
package java.lang;

// Class names looks like: MyClass
public final class System {}

// method name
private static native void registerNatives();

// constructor
private System() {}

// member variables
public static final InputStream in = null;
private static String notSupportedJnuEncoding;

// constants
private static final int NEVER = 1;
```

It using `//` and `/**/` as comments, same as C++.

Listing 1: Hello.java

```
// Usage 1:
// java Hello.java
// Usage 2:
// javac Hello.java
// java Hello
//
// Note:
// - "javac Hello.java" generates a file "Hello.class"
// - "java Hello" takes as input "Hello.class" and executes it
//
// The class name Hello must match the filename Hello.java
// By convention, the class name looks like `MyClass`.
class Hello {
    // Note: How is array defined in java
    public static void main(String[] args) {
        System.out.println("hello world");
    }
} // There is no ';' here
// Every line of runnable code must be in some `class`
```

Listing 2: EqualTest.java

```
class EqualTest {
```

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```

public int i;

public EqualTest(int a) {
    this.i = a;
}

public boolean equals(Object anObject) {
    if (this == anObject) {
        return true;
    }
    if (anObject instanceof EqualTest) {
        return this.i == ((EqualTest) anObject).i;
    }
    return false;
}

public static void main(String[] args) {
    EqualTest e1 = new EqualTest(10);
    EqualTest e2 = new EqualTest(10);

    System.out.println(e1 == e2); // false, compare the reference
    System.out.println(e1 != e2); // true
    System.out.println(e1.equals(e2)); // true, compare the contained value
}
}

```

Listing 3: Variables.java

```

class Variables {
    public static void main(String[] args) {
        String msg = "Hello world";
        int i = 10;
        i++; // ok
        ++i; // ok
        // i-- // error, should be --i
        --i;
        int ii = i % 2;
        i = 10;
        ii = i / 3; // truncated
        System.out.println(ii); // 3
        ii += 2;
        System.out.println(ii); // 5
        // also has:
        // -=, &=, |=, >>=, <<=, ^=, /=, *=
        // Similar to C/C++

        /* float f = 1.25; // error: possible lossy conversion from double to float */
        // Caution: We have to use `1.25f` instead of `1.25` to assign a float variable
        float f = 1.25f;
        double d = 1.25;
        d = 1.25d; // also ok
    }
}

```

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```

// f = d; // error: possible lossy conversion from double to float
f = (float) d; // ok, explicit cast
d = f; // ok

char c = 'h'; // a character

i = 10;
System.out.println(msg);
System.out.println(i); // 10
System.out.println(f); // 1.25
System.out.println(d); // 1.25
System.out.println(c); // h

// define multiple variable in the same line
int i1 = 1, i2;
// System.out.println(i2); // variable i2 might not have been initialized
i2 = 3;
System.out.println(i2); // 3
boolean b = false;
System.out.println(b); // false
b = true;
// b = 1; // error: int cannot be converted to boolean
System.out.println(b); // true

// byte b0 = 128; // error: lossy conversion from int to byte
byte b0 = 127; // ok
/* b0 = -129; // error: lossy conversion from int to type */
b0 = -128; // ok

// short s0 = 32768; // error: lossy conversion from int to short
short s0 = 32767; // ok
// s0 = -32769; // error: lossy conversion from int to short
s0 = -32768; // ok

// other types: int, long, float, double, boolean, char
// Note: char has 2-byte
// boolean has 1-bit
// There are no unsigned integers !!

// ternary operator :?
System.out.println(2 > 3 ? "yes" : "no"); // no
}
}

```

Listing 4: Strings.java

```

class Strings {
    public static void main(String[] args) {
        String s = "abc";
        System.out.println(s.length()); // 3
        System.out.println(s.toUpperCase()); // ABC
        System.out.println(s.toUpperCase().toLowerCase()); // abc
    }
}

```

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```

System.out.println(s.indexOf("ab")); // 0
System.out.println(s.indexOf("a")); // 0
System.out.println(s.indexOf("bc")); // 1
System.out.println(s.indexOf("bca")); // when not found, it is -1

System.out.println(s.charAt(0) == 'a'); // true
System.out.println(s + "123" == "abc123"); // false, == compares the reference
System.out.println((s + "123").equals("abc123")); // true, compare the content
System.out.println(s.concat("123").equals("abc123")); // true, compare the content
System.out.println((s + 123).equals("abc123")); // true, compare the content
System.out.println((123 + s).equals("123abc")); // true, compare the content
s = "a\\b";
}
}
;

```

Listing 5: MathTest.java

```

class MathTest {
    public static void main(String[] args) {
        System.out.println(Math.max(2, 3)); // 3
        System.out.println(Math.max(2, 3.5)); // 3.5
        System.out.println(Math.min(2, 3.5)); // 2
        System.out.println(Math.sqrt(6.25)); // 2.5
        System.out.println(Math.sqrt(9)); // 3.0, note it is a double
        System.out.println(Math.abs(-9)); // -9
        System.out.println(Math.abs(-9.0)); // -9.0
        System.out.println(Math.random()); // a number in the range [0, 1)
    }
}

```

Listing 6: ArrayTest.java

```

class ArrayTest {
    public static void main(String[] args) {
        int[] a = {1, 2, 3};
        for (int i : a) {
            System.out.println(i);
        }
        /*
        1
        2
        3
        */
        System.out.println(a[0]); // 1
        System.out.println(a.length); // 3
        for (int i = 0; i != a.length; ++i) {
            System.out.println(a[i]);
        }
        /*
        1
        2
        */
    }
}

```

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```
    3
    */
}
```

### 10.2.1 TODOs

1. How to define an array? How to iterate an array?
2. What methods does the `String` class have
3. What are final variables?
4. How to define a package?
5. What is static import?
6. What is a lambda expression?
7. How to write comments using javadoc?
8. How to generate documentation from javadoc?
9. How to use a for-each loop?
10. How to import a class from another file?

## 10.3 Reference

- <https://www.w3schools.com/java/default.asp>
- <https://docs.oracle.com/javase/tutorial/>
- <https://docs.oracle.com/en/java/javase/17/docs/api/index.html>
- <https://github.com/openjdk/jdk.git>

Clone it and you can find the source code in `src/java.base/share/classes/java/lang/System.java` for `java.lang.System`.

## JAVASCRIPT

### 11.1 Hello world

```
console.log('hello world')
console.log(eval('3 + 5'))
```

To write multi-line javascript, use shift + Enter for a new line.

```
(function(){
    "use strict";
    /* Start of your code */
    function greetMe(yourName) {
        alert('Hello ' + yourName);
    }

    greetMe('World');
    /* End of your code */
})();
```

It is case sensitive. Statements are separated by ;. Comments are the same as in C/C++.

#### 11.1.1 array

Listing 1: ./code/hello\_world/array.js

```
1 let a = [ 1, 2, 3 ];
2 function sum(arr) {
3     let s = 0;
4     for (let x of arr) {
5         s += x;
6     }
7     return s;
8 }
9 // Sum of the array [1,2,3] is 6
10 console.log('Sum of the array [' + a + '] is ' + sum(a));
11
12 function sum2(arr) {
13     let s = 0;
14     for (let i = 0; i != arr.length; ++i) {
```

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```
15     s += arr[i];
16   }
17   return s;
18 }
19 console.log(sum2(a)); // 6
```

Note that there are two ways to iterate an array:

- `for(let x of array)`
- `for(let i = 0; i != array.length; ++i) { ... }`

To run the above code, use:

```
node array.js
```

## 11.1.2 class

Listing 2: `./code/hello_world/class.js`

```
1 class Point {
2   constructor(x, y) {
3     this.x = x;
4     this.y = y;
5   }
6
7   distance() { return Math.sqrt(this.x * this.x + this.y * this.y); }
8 }
9
10 let p = new Point(1, 1);
11 console.log(p.distance()); // 1.4142135623730951
```

It defines a `Point` class with two fields `x`, `y`. `Point` has two methods: a constructor and a method `distance()`.

Note that class names are by convention capitalized.

## 11.2 node

Go to <https://nodejs.org/en/download/> to download pre-built binaries:

```
wget https://nodejs.org/dist/v16.15.1/node-v16.15.1-linux-x64.tar.xz
tar xvf node-v16.15.1-linux-x64.tar.xz
```

and then add `/path/to/node-v16.15.1-linux-x64/bin/` to `PATH`.

## 11.3 TODOs

1. This page [https://developer.mozilla.org/en-US/docs/Learn/Getting\\_started\\_with\\_the\\_web/Installing\\_basic\\_software](https://developer.mozilla.org/en-US/docs/Learn/Getting_started_with_the_web/Installing_basic_software) lists some tools to minify code:
  - WebPack: <https://webpack.js.org/>
  - Grunt: <https://gruntjs.com/>
  - Gulp: <https://gulpjs.com/>
2. Color picker tool: [https://developer.mozilla.org/en-US/docs/Web/CSS/CSS\\_Colors/Color\\_picker\\_tool](https://developer.mozilla.org/en-US/docs/Web/CSS/CSS_Colors/Color_picker_tool)
3. Google font: <https://fonts.google.com/> and [https://developers.google.com/fonts/docs/getting\\_started](https://developers.google.com/fonts/docs/getting_started)



## 12.1 Hello world

Listing 1: hello\_world.html

```
<!DOCTYPE html>
<html>
  <head>
    <meta charset="utf-8">
    <title>Hello World</title>
  </head>
  <body>
    <p>Hello world</p>
  </body>
</html>
```

### 12.1.1 comments

```
<!-- this is a comment -->
```

### 12.1.2 images

```
</img>
</img>
</img>
```

### 12.1.3 ordered lists

```
<p> The following points </p>

<ol>
  <li> First </li>
  <li> Second </li>
</ol>
```

### 12.1.4 unordered lists

```
<p> The following points </p>

<ul>
  <li> foo </li>
  <li> bar </li>
</ul>
```

### 12.1.5 links

```
<a href="https://www.google.com">some text</a>
```

## 12.2 References

- Structuring the web with HTML  
<https://developer.mozilla.org/en-US/docs/Learn/HTML>



## 13.1 Hello world

### 13.1.1 comment

```
/* this is a comment */
```

```
p { color: red; }
```

Then, in some html file, use:

```
<link href="abc/foo.css" rel="stylesheet">
```

### 13.1.2 Selector

- tag name or element name: e.g., p selects <p>; h1 selects <h1>.
- ID:, e.g., #my-id selects <a id="my-id"> or <p id="my-id">
- class: e.g., .my-class selects <a class="my-class"> and <p class="my-class">
- attribute: e.g., img[src] selects  but not <img>

See [https://developer.mozilla.org/en-US/docs/Learn/Getting\\_started\\_with\\_the\\_web/CSS\\_basics#different\\_types\\_of\\_selectors](https://developer.mozilla.org/en-US/docs/Learn/Getting_started_with_the_web/CSS_basics#different_types_of_selectors) and [https://developer.mozilla.org/en-US/docs/Learn/CSS/Building\\_blocks/Selectors](https://developer.mozilla.org/en-US/docs/Learn/CSS/Building_blocks/Selectors) for more.

Example with multiple rules:

Listing 1: Example with multiple rules

```
p {  
  color: red;  
  width: 500px;  
  border: 1px solid black;  
}
```

Example with multiple selectors:

Listing 2: Example with multiple selectors

```
p, li, h1 { color: red; }
```

## 13.2 References

- CSS basics

[https://developer.mozilla.org/en-US/docs/Learn/Getting\\_started\\_with\\_the\\_web/CSS\\_basics](https://developer.mozilla.org/en-US/docs/Learn/Getting_started_with_the_web/CSS_basics)

## **14.1 GIL**



## PROTOCOL BUFFERS

### 15.1 Installation

#### 15.1.1 C++

See <https://github.com/protocolbuffers/protobuf/blob/main/src/README.md>.

```
make protocol-buffers
cd protocol-buffers
wget https://github.com/protocolbuffers/protobuf/releases/download/v3.20.1/protobuf-all-
↪3.20.1.tar.gz
tar xvf protobuf-all-3.20.1.tar.gz
cd protobuf-all-3.20.1
./configure --prefix=$HOME/software/protobuf-3.20.1
make -j 20
make -j 10 check
make install 2>&1 | tee my-log.txt
cd $HOME/software/protobuf-3.20.1
tree . > tree-log.txt
```

```
$ export PKG_CONFIG_PATH=$HOME/software/protobuf-3.20.1:$PKG_CONFIG_PATH

$ pkg-config --cflags protobuf
-I/root/fangjun/software/protobuf-3.20.1/include

$ pkg-config --libs protobuf
-L/root/fangjun/software/protobuf-3.20.1/lib -lprotobuf

$ pkg-config --cflags --libs protobuf
-I/root/fangjun/software/protobuf-3.20.1/include -L/root/fangjun/software/protobuf-3.20.
↪1/lib -lprotobuf

$ pkg-config --libs-only-L protobuf
-L/root/fangjun/software/protobuf-3.20.1/lib

$ pkg-config --libs-only-l protobuf
-lprotobuf
```

```
$ export PATH=$HOME/software/protobuf-3.20.1/bin:$PATH
$ protoc --version
libprotoc 3.20.1
```

Listing 1: ./code/my-log.txt (Installation logs)

```
1 Making install in .
2 make[1]: Entering directory '/ceph-fj/fangjun/open-source-2/protocol-buffers/protobuf-3.
  ↳ 20.1'
3 make[2]: Entering directory '/ceph-fj/fangjun/open-source-2/protocol-buffers/protobuf-3.
  ↳ 20.1'
4 make[2]: Nothing to be done for 'install-exec-am'.
5 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/lib/pkgconfig'
6 /usr/bin/install -c -m 644 protobuf.pc protobuf-lite.pc '/root/fangjun/software/
  ↳ protobuf-3.20.1/lib/pkgconfig'
7 make[2]: Leaving directory '/ceph-fj/fangjun/open-source-2/protocol-buffers/protobuf-3.
  ↳ 20.1'
8 make[1]: Leaving directory '/ceph-fj/fangjun/open-source-2/protocol-buffers/protobuf-3.
  ↳ 20.1'
9 Making install in src
10 make[1]: Entering directory '/ceph-fj/fangjun/open-source-2/protocol-buffers/protobuf-3.
  ↳ 20.1/src'
11 make[2]: Entering directory '/ceph-fj/fangjun/open-source-2/protocol-buffers/protobuf-3.
  ↳ 20.1/src'
12 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/lib'
13 /bin/bash ../libtool --mode=install /usr/bin/install -c libprotobuf-lite.la
  ↳ libprotobuf.la libprotoc.la '/root/fangjun/software/protobuf-3.20.1/lib'
14 libtool: install: /usr/bin/install -c .libs/libprotobuf-lite.so.31.0.1 /root/fangjun/
  ↳ software/protobuf-3.20.1/lib/libprotobuf-lite.so.31.0.1
15 libtool: install: (cd /root/fangjun/software/protobuf-3.20.1/lib && { ln -s -f
  ↳ libprotobuf-lite.so.31.0.1 libprotobuf-lite.so.31 || { rm -f libprotobuf-lite.so.31 &&
  ↳ ln -s libprotobuf-lite.so.31.0.1 libprotobuf-lite.so.31; }; })
16 libtool: install: (cd /root/fangjun/software/protobuf-3.20.1/lib && { ln -s -f
  ↳ libprotobuf-lite.so.31.0.1 libprotobuf-lite.so || { rm -f libprotobuf-lite.so && ln -s
  ↳ libprotobuf-lite.so.31.0.1 libprotobuf-lite.so; }; })
17 libtool: install: /usr/bin/install -c .libs/libprotobuf-lite.lai /root/fangjun/software/
  ↳ protobuf-3.20.1/lib/libprotobuf-lite.la
18 libtool: install: /usr/bin/install -c .libs/libprotobuf.so.31.0.1 /root/fangjun/software/
  ↳ protobuf-3.20.1/lib/libprotobuf.so.31.0.1
19 libtool: install: (cd /root/fangjun/software/protobuf-3.20.1/lib && { ln -s -f
  ↳ libprotobuf.so.31.0.1 libprotobuf.so.31 || { rm -f libprotobuf.so.31 && ln -s
  ↳ libprotobuf.so.31.0.1 libprotobuf.so.31; }; })
20 libtool: install: (cd /root/fangjun/software/protobuf-3.20.1/lib && { ln -s -f
  ↳ libprotobuf.so.31.0.1 libprotobuf.so || { rm -f libprotobuf.so && ln -s libprotobuf.so.
  ↳ 31.0.1 libprotobuf.so; }; })
21 libtool: install: /usr/bin/install -c .libs/libprotobuf.lai /root/fangjun/software/
  ↳ protobuf-3.20.1/lib/libprotobuf.la
22 libtool: warning: relinking 'libprotoc.la'
23 libtool: install: (cd /root/fangjun/open-source-2/protocol-buffers/protobuf-3.20.1/src; /
  ↳ bin/bash "/root/fangjun/open-source-2/protocol-buffers/protobuf-3.20.1/libtool" --
  ↳ silent --tag CXX --mode=relink g++ -pthread -DHAVE_PTHREAD=1 -DHAVE_ZLIB=1 -Wall -Wno-
  ↳ sign-compare -O2 -g -std=c++11 -DDEBUG -version-info 31:1:0 -export-dynamic -no-
  ↳ undefined -Wl,--version-script=../libprotoc.map -o libprotoc.la -rpath /root/fangjun/
  ↳ software/protobuf-3.20.1/lib google/protobuf/compiler/code_generator.lo google/
  ↳ protobuf/compiler/command_line_interface.lo google/protobuf/compiler/cpp/cpp_enum.lo
  ↳ google/protobuf/compiler/cpp/cpp_enum_field.lo google/protobuf/compiler/cpp/cpp_
  ↳ extension.lo google/protobuf/compiler/cpp/cpp_field.lo google/protobuf/compiler/cpp/
  ↳ cpp_file.lo google/protobuf/compiler/cpp/cpp_generator.lo google/protobuf/compiler/cpp/
  ↳ cpp_helpers.lo google/protobuf/compiler/cpp/cpp_map_field.lo google/protobuf/compiler/
  ↳ cpp/cpp_message.lo google/protobuf/compiler/cpp/cpp_message_field.lo google/protobuf/
  ↳ (continues on next page)
```

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```

24 libtool: install: /usr/bin/install -c .libs/libprotoc.so.31.0.1T /root/fangjun/software/
↳protobuf-3.20.1/lib/libprotoc.so.31.0.1
25 libtool: install: (cd /root/fangjun/software/protobuf-3.20.1/lib && { ln -s -f libprotoc.
↳so.31.0.1 libprotoc.so.31 || { rm -f libprotoc.so.31 && ln -s libprotoc.so.31.0.1
↳libprotoc.so.31; }; })
26 libtool: install: (cd /root/fangjun/software/protobuf-3.20.1/lib && { ln -s -f libprotoc.
↳so.31.0.1 libprotoc.so || { rm -f libprotoc.so && ln -s libprotoc.so.31.0.1 libprotoc.
↳so; }; })
27 libtool: install: /usr/bin/install -c .libs/libprotoc.lai /root/fangjun/software/
↳protobuf-3.20.1/lib/libprotoc.la
28 libtool: install: /usr/bin/install -c .libs/libprotobuf-lite.a /root/fangjun/software/
↳protobuf-3.20.1/lib/libprotobuf-lite.a
29 libtool: install: chmod 644 /root/fangjun/software/protobuf-3.20.1/lib/libprotobuf-lite.a
30 libtool: install: ranlib /root/fangjun/software/protobuf-3.20.1/lib/libprotobuf-lite.a
31 libtool: install: /usr/bin/install -c .libs/libprotobuf.a /root/fangjun/software/
↳protobuf-3.20.1/lib/libprotobuf.a
32 libtool: install: chmod 644 /root/fangjun/software/protobuf-3.20.1/lib/libprotobuf.a
33 libtool: install: ranlib /root/fangjun/software/protobuf-3.20.1/lib/libprotobuf.a
34 libtool: install: /usr/bin/install -c .libs/libprotoc.a /root/fangjun/software/protobuf-
↳3.20.1/lib/libprotoc.a
35 libtool: install: chmod 644 /root/fangjun/software/protobuf-3.20.1/lib/libprotoc.a
36 libtool: install: ranlib /root/fangjun/software/protobuf-3.20.1/lib/libprotoc.a
37 libtool: finish: PATH="/ceph-fj/fangjun/software/py38/bin:/ceph-fj/fangjun/software/jdk-
↳17.0.3/bin:/ceph-fj/fangjun/software/cmake/bin:/ceph-fj/fangjun/software/texlive2021-
↳20210325/bin/x86_64-linux:/ceph-sh1/fangjun/software/cuda-10.2.89/bin:/ceph-fj/fangjun/
↳software/bin:/ceph-sh1/fangjun/software/bin:/ceph-sh1/fangjun/software/nvim-linux64/
↳bin:/ceph-fj/fangjun/software/py38/bin:/ceph-fj/fangjun/software/cmake/bin:/ceph-fj/
↳fangjun/software/texlive2021-20210325/bin/x86_64-linux:/ceph-sh1/fangjun/software/cuda-
↳10.2.89/bin:/ceph-sh1/fangjun/software/nvim-linux64/bin:/usr/local/sbin:/usr/local/
↳bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/games:/sbin" ldconfig -n /root/fangjun/software/
↳protobuf-3.20.1/lib
38 -----
39 Libraries have been installed in:
40   /root/fangjun/software/protobuf-3.20.1/lib
41
42 If you ever happen to want to link against installed libraries
43 in a given directory, LIBDIR, you must either use libtool, and
44 specify the full pathname of the library, or use the '-LLIBDIR'
45 flag during linking and do at least one of the following:
46   - add LIBDIR to the 'LD_LIBRARY_PATH' environment variable
47     during execution
48   - add LIBDIR to the 'LD_RUN_PATH' environment variable
49     during linking
50   - use the '-Wl,-rpath -Wl,LIBDIR' linker flag
51   - have your system administrator add LIBDIR to '/etc/ld.so.conf'
52
53 See any operating system documentation about shared libraries for
54 more information, such as the ld(1) and ld.so(8) manual pages.
55 -----
56 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/bin'
57 /bin/bash ../libtool --mode=install /usr/bin/install -c protoc '/root/fangjun/
↳software/protobuf-3.20.1/bin'

```

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```

58 libtool: install: /usr/bin/install -c .libs/protoc /root/fangjun/software/protobuf-3.20.
    ↪ 1/bin/protoc
59 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include'
60 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf'
61 /usr/bin/install -c -m 644 google/protobuf/any.proto google/protobuf/api.proto google/
    ↪ protobuf/descriptor.proto google/protobuf/duration.proto google/protobuf/empty.proto
    ↪ google/protobuf/field_mask.proto google/protobuf/source_context.proto google/protobuf/
    ↪ struct.proto google/protobuf/timestamp.proto google/protobuf/type.proto google/
    ↪ protobuf/wrappers.proto '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf
    ↪ '
62 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler'
63 /usr/bin/install -c -m 644 google/protobuf/compiler/plugin.proto '/root/fangjun/
    ↪ software/protobuf-3.20.1/include/google/protobuf/compiler'
64 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include'
65 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf'
66 /usr/bin/install -c -m 644 google/protobuf/any.h google/protobuf/any.pb.h google/
    ↪ protobuf/api.pb.h google/protobuf/arena.h google/protobuf/arena_impl.h google/protobuf/
    ↪ arenastring.h google/protobuf/arenaz_sampler.h google/protobuf/descriptor.h google/
    ↪ protobuf/descriptor.pb.h google/protobuf/descriptor_database.h google/protobuf/
    ↪ duration.pb.h google/protobuf/dynamic_message.h google/protobuf/empty.pb.h google/
    ↪ protobuf/explicitly_constructed.h google/protobuf/extension_set.h google/protobuf/
    ↪ extension_set_inl.h google/protobuf/field_access_listener.h google/protobuf/field_mask.
    ↪ pb.h google/protobuf/generated_enum_reflection.h google/protobuf/generated_enum_util.h
    ↪ google/protobuf/generated_message_bases.h google/protobuf/generated_message_reflection.
    ↪ h google/protobuf/generated_message_tctable_decl.h google/protobuf/generated_message_
    ↪ tctable_impl.h google/protobuf/generated_message_util.h google/protobuf/has_bits.h
    ↪ google/protobuf/implicit_weak_message.h google/protobuf/inlined_string_field.h google/
    ↪ protobuf/map.h google/protobuf/map_entry.h google/protobuf/map_entry_lite.h google/
    ↪ protobuf/map_field.h google/protobuf/map_field_inl.h google/protobuf/map_field_lite.h
    ↪ google/protobuf/map_type_handler.h google/protobuf/message.h google/protobuf/message_
    ↪ lite.h google/protobuf/metadata.h google/protobuf/metadata_lite.h google/protobuf/
    ↪ parse_context.h '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf'
67 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
    ↪ js'
68 /usr/bin/install -c -m 644 google/protobuf/compiler/js/js_generator.h '/root/fangjun/
    ↪ software/protobuf-3.20.1/include/google/protobuf/compiler/js'
69 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
    ↪ cpp'
70 /usr/bin/install -c -m 644 google/protobuf/compiler/cpp/cpp_file.h google/protobuf/
    ↪ compiler/cpp/cpp_generator.h google/protobuf/compiler/cpp/cpp_helpers.h google/
    ↪ protobuf/compiler/cpp/cpp_names.h '/root/fangjun/software/protobuf-3.20.1/include/
    ↪ google/protobuf/compiler/cpp'
71 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
    ↪ ruby'
72 /usr/bin/install -c -m 644 google/protobuf/compiler/ruby/ruby_generator.h '/root/
    ↪ fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/ruby'
73 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
    ↪ python'
74 /usr/bin/install -c -m 644 google/protobuf/compiler/python/python_generator.h google/
    ↪ protobuf/compiler/python/python_pyi_generator.h '/root/fangjun/software/protobuf-3.20.
    ↪ 1/include/google/protobuf/compiler/python'
75 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/util'

```

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```

76 /usr/bin/install -c -m 644 google/protobuf/util/delimited_message_util.h google/
↳ protobuf/util/field_comparator.h google/protobuf/util/field_mask_util.h google/
↳ protobuf/util/json_util.h google/protobuf/util/message_differencer.h google/protobuf/
↳ util/time_util.h google/protobuf/util/type_resolver.h google/protobuf/util/type_
77 ↳ resolver_util.h '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/util'
78 /usr/bin/install -c -m 644 google/protobuf/io/coded_stream.h google/protobuf/io/gzip_
↳ stream.h google/protobuf/io/io_win32.h google/protobuf/io/printer.h google/protobuf/io/
↳ strtod.h google/protobuf/io/tokenizer.h google/protobuf/io/zero_copy_stream.h google/
↳ protobuf/io/zero_copy_stream_impl.h google/protobuf/io/zero_copy_stream_impl_lite.h '/'
79 ↳ root/fangjun/software/protobuf-3.20.1/include/google/protobuf/io'
↳ /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
↳ csharp'
80 /usr/bin/install -c -m 644 google/protobuf/compiler/csharp/csharp_doc_comment.h google/
↳ protobuf/compiler/csharp/csharp_generator.h google/protobuf/compiler/csharp/csharp_
↳ names.h google/protobuf/compiler/csharp/csharp_options.h '/root/fangjun/software/
↳ protobuf-3.20.1/include/google/protobuf/compiler/csharp'
81 ↳ /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
↳ php'
82 /usr/bin/install -c -m 644 google/protobuf/compiler/php/php_generator.h '/root/fangjun/
↳ software/protobuf-3.20.1/include/google/protobuf/compiler/php'
83 ↳ /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/stubs'
84 /usr/bin/install -c -m 644 google/protobuf/stubs/bytestream.h google/protobuf/stubs/
↳ callback.h google/protobuf/stubs/casts.h google/protobuf/stubs/common.h google/
↳ protobuf/stubs/hash.h google/protobuf/stubs/logging.h google/protobuf/stubs/macros.h
↳ google/protobuf/stubs/map_util.h google/protobuf/stubs/mutex.h google/protobuf/stubs/
↳ once.h google/protobuf/stubs/platform_macros.h google/protobuf/stubs/port.h google/
↳ protobuf/stubs/status.h google/protobuf/stubs/stl_util.h google/protobuf/stubs/
↳ stringpiece.h google/protobuf/stubs/strutil.h google/protobuf/stubs/template_util.h '/'
85 ↳ root/fangjun/software/protobuf-3.20.1/include/google/protobuf/stubs'
↳ /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
↳ java'
86 /usr/bin/install -c -m 644 google/protobuf/compiler/java/java_generator.h google/
↳ protobuf/compiler/java/java_kotlin_generator.h google/protobuf/compiler/java/java_
↳ names.h '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/java'
87 ↳ /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf'
88 /usr/bin/install -c -m 644 google/protobuf/port.h google/protobuf/port_def.inc google/
↳ protobuf/port_undef.inc google/protobuf/reflection.h google/protobuf/reflection_ops.h
↳ google/protobuf/repeated_field.h google/protobuf/repeated_ptr_field.h google/protobuf/
↳ service.h google/protobuf/source_context.pb.h google/protobuf/struct.pb.h google/
↳ protobuf/text_format.h google/protobuf/timestamp.pb.h google/protobuf/type.pb.h google/
↳ protobuf/unknown_field_set.h google/protobuf/wire_format.h google/protobuf/wire_format_
↳ lite.h google/protobuf/wrappers.pb.h '/root/fangjun/software/protobuf-3.20.1/include/
↳ google/protobuf'
89 ↳ /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
↳ objectivec'
90 /usr/bin/install -c -m 644 google/protobuf/compiler/objectivec/objectivec_generator.h
↳ google/protobuf/compiler/objectivec/objectivec_helpers.h '/root/fangjun/software/
↳ protobuf-3.20.1/include/google/protobuf/compiler/objectivec'
91 ↳ /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler'
92 /usr/bin/install -c -m 644 google/protobuf/compiler/code_generator.h google/protobuf/
↳ compiler/command_line_interface.h google/protobuf/compiler/importer.h google/protobuf/
↳ compiler/parser.h google/protobuf/compiler/plugin.h google/protobuf/compiler/plugin.pb
↳ h '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler'

```

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```

93 make[2]: Leaving directory '/ceph-fj/fangjun/open-source-2/protocol-buffers/protobuf-3.
    ↳20.1/src'
94 make[1]: Leaving directory '/ceph-fj/fangjun/open-source-2/protocol-buffers/protobuf-3.
    ↳20.1/src'

```

Listing 2: ./code/tree-log.txt (Installed files)

```

1  .
2  |-- bin
3  |   |-- protoc
4  |-- include
5  |   |-- google
6  |       |-- protobuf
7  |           |-- any.h
8  |           |-- any.pb.h
9  |           |-- any.proto
10 |           |-- api.pb.h
11 |           |-- api.proto
12 |           |-- arena.h
13 |           |-- arena_impl.h
14 |           |-- arenastring.h
15 |           |-- arenaz_sampler.h
16 |           |-- compiler
17 |               |-- code_generator.h
18 |               |-- command_line_interface.h
19 |               |-- cpp
20 |                   |-- cpp_file.h
21 |                   |-- cpp_generator.h
22 |                   |-- cpp_helpers.h
23 |                   |-- cpp_names.h
24 |               |-- csharp
25 |                   |-- csharp_doc_comment.h
26 |                   |-- csharp_generator.h
27 |                   |-- csharp_names.h
28 |                   |-- csharp_options.h
29 |               |-- importer.h
30 |               |-- java
31 |                   |-- java_generator.h
32 |                   |-- java_kotlin_generator.h
33 |                   |-- java_names.h
34 |               |-- js
35 |                   |-- js_generator.h
36 |               |-- objectivec
37 |                   |-- objectivec_generator.h
38 |                   |-- objectivec_helpers.h
39 |               |-- parser.h
40 |               |-- php
41 |                   |-- php_generator.h
42 |               |-- plugin.h
43 |               |-- plugin.pb.h
44 |               |-- plugin.proto
45 |               |-- python

```

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```

46 |         | | | -- python_generator.h
47 |         | | | -- python_pyi_generator.h
48 |         | | | -- ruby
49 |         | | | -- ruby_generator.h
50 |         | -- descriptor.h
51 |         | -- descriptor.pb.h
52 |         | -- descriptor.proto
53 |         | -- descriptor_database.h
54 |         | -- duration.pb.h
55 |         | -- duration.proto
56 |         | -- dynamic_message.h
57 |         | -- empty.pb.h
58 |         | -- empty.proto
59 |         | -- explicitly_constructed.h
60 |         | -- extension_set.h
61 |         | -- extension_set_inl.h
62 |         | -- field_access_listener.h
63 |         | -- field_mask.pb.h
64 |         | -- field_mask.proto
65 |         | -- generated_enum_reflection.h
66 |         | -- generated_enum_util.h
67 |         | -- generated_message_bases.h
68 |         | -- generated_message_reflection.h
69 |         | -- generated_message_tctable_decl.h
70 |         | -- generated_message_tctable_impl.h
71 |         | -- generated_message_util.h
72 |         | -- has_bits.h
73 |         | -- implicit_weak_message.h
74 |         | -- inlined_string_field.h
75 |         | -- io
76 |         | | -- coded_stream.h
77 |         | | -- gzip_stream.h
78 |         | | -- io_win32.h
79 |         | | -- printer.h
80 |         | | -- strtod.h
81 |         | | -- tokenizer.h
82 |         | | -- zero_copy_stream.h
83 |         | | -- zero_copy_stream_impl.h
84 |         | | -- zero_copy_stream_impl_lite.h
85 |         | -- map.h
86 |         | -- map_entry.h
87 |         | -- map_entry_lite.h
88 |         | -- map_field.h
89 |         | -- map_field_inl.h
90 |         | -- map_field_lite.h
91 |         | -- map_type_handler.h
92 |         | -- message.h
93 |         | -- message_lite.h
94 |         | -- metadata.h
95 |         | -- metadata_lite.h
96 |         | -- parse_context.h
97 |         | -- port.h

```

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```
98 |         |-- port_def.inc
99 |         |-- port_undef.inc
100 |         |-- reflection.h
101 |         |-- reflection_ops.h
102 |         |-- repeated_field.h
103 |         |-- repeated_ptr_field.h
104 |         |-- service.h
105 |         |-- source_context.pb.h
106 |         |-- source_context.proto
107 |         |-- struct.pb.h
108 |         |-- struct.proto
109 |         |-- stubs
110 |         |   |-- bytestream.h
111 |         |   |-- callback.h
112 |         |   |-- casts.h
113 |         |   |-- common.h
114 |         |   |-- hash.h
115 |         |   |-- logging.h
116 |         |   |-- macros.h
117 |         |   |-- map_util.h
118 |         |   |-- mutex.h
119 |         |   |-- once.h
120 |         |   |-- platform_macros.h
121 |         |   |-- port.h
122 |         |   |-- status.h
123 |         |   |-- stl_util.h
124 |         |   |-- stringpiece.h
125 |         |   |-- strutil.h
126 |         |   `-- template_util.h
127 |         |-- text_format.h
128 |         |-- timestamp.pb.h
129 |         |-- timestamp.proto
130 |         |-- type.pb.h
131 |         |-- type.proto
132 |         |-- unknown_field_set.h
133 |         |-- util
134 |         |   |-- delimited_message_util.h
135 |         |   |-- field_comparator.h
136 |         |   |-- field_mask_util.h
137 |         |   |-- json_util.h
138 |         |   |-- message_differencer.h
139 |         |   |-- time_util.h
140 |         |   |-- type_resolver.h
141 |         |   `-- type_resolver_util.h
142 |         |-- wire_format.h
143 |         |-- wire_format_lite.h
144 |         |-- wrappers.pb.h
145 |         `-- wrappers.proto
146 |-- lib
147 |   |-- libprotobuf-lite.a
148 |   |-- libprotobuf-lite.la
149 |   |-- libprotobuf-lite.so -> libprotobuf-lite.so.31.0.1
```

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```

150 | |-- libprotobuf-lite.so.31 -> libprotobuf-lite.so.31.0.1
151 | |-- libprotobuf-lite.so.31.0.1
152 | |-- libprotobuf.a
153 | |-- libprotobuf.la
154 | |-- libprotobuf.so -> libprotobuf.so.31.0.1
155 | |-- libprotobuf.so.31 -> libprotobuf.so.31.0.1
156 | |-- libprotobuf.so.31.0.1
157 | |-- libprotoc.a
158 | |-- libprotoc.la
159 | |-- libprotoc.so -> libprotoc.so.31.0.1
160 | |-- libprotoc.so.31 -> libprotoc.so.31.0.1
161 | |-- libprotoc.so.31.0.1
162 | `-- pkgconfig
163 |     |-- protobuf-lite.pc
164 |     `-- protobuf.pc
165 |-- tree-log.txt
166
167 18 directories, 146 files

```

## 15.1.2 Install with cmake

```

make protocol-buffers
cd protocol-buffers
wget https://github.com/protocolbuffers/protobuf/releases/download/v3.20.1/protobuf-all-
↪3.20.1.tar.gz
tar xvf protobuf-all-3.20.1.tar.gz
cd protobuf-all-3.20.1
mkdir my-build
cd my-build
cmake -Dprotobuf_BUILD_SHARED_LIBS=ON -DCMAKE_INSTALL_PREFIX=/ceph-fj/fangjun/software/
↪protobuf-3.20.1-cmake/ ../cmake 2>&1 | tee cmake-configure-shared-lib.log
make -j10 2>&1 | tee make-shared.log
make install 2>&1 | tee make-shared-install.log

cd $HOME/software/protobuf-3.20.1-cmake
tree . > tree-cmake-log.txt

```

## 15.2 Hello

### 15.2.1 hello.proto

See

- <https://developers.google.com/protocol-buffers/docs/cpptutorial>
- <https://developers.google.com/protocol-buffers/docs/pythontutorial>

Listing 3: ./code/hello.proto

```
1 syntax = "proto2";
2
3 package tutorial;
4
5 // available types:
6 // bool, int32, float, double, string
7 message Person {
8     optional string name = 1;
9     optional int32 id = 2;
10    optional string email = 3;
11
12    enum PhoneType {
13        MOBILE = 0;
14        HOME = 1;
15        WORK = 2;
16    }
17
18    message PhoneNumber {
19        optional string number = 1;
20        optional PhoneType type = 2 [ default = HOME ];
21    }
22
23    repeated PhoneNumber phones = 4;
24 }
25
26 message AddressBook { repeated Person people = 1; }
```

## 15.2.2 makefile

Listing 4: ./code/Makefile

```

1 .PHONY: all clean
2
3 all: hello.pb.cc hello.pb.h hello_pb2.py
4
5 hello.pb.cc hello.pb.h: hello.proto
6     protoc -I=./ --cpp_out=./ ./hello.proto
7
8 hello_pb2.py: hello.proto
9     protoc -I=./ --python_out=./ ./hello.proto
10
11 clean:
12     $(RM) hello.pb.cc hello.pb.h hello_pb2.py

```

### 15.2.3 hello.pb.h

Listing 5: ./code/hello.pb.h

```

1 // Generated by the protocol buffer compiler.  DO NOT EDIT!
2 // source: hello.proto
3
4 #ifndef GOOGLE_PROTOBUF_INCLUDED_hello_2eproto
5 #define GOOGLE_PROTOBUF_INCLUDED_hello_2eproto
6
7 #include <limits>
8 #include <string>
9
10 #include <google/protobuf/port_def.inc>
11 #if PROTOBUF_VERSION < 3020000
12 #error This file was generated by a newer version of protoc which is
13 #error incompatible with your Protocol Buffer headers. Please update
14 #error your headers.
15 #endif
16 #if 3020001 < PROTOBUF_MIN_PROTOC_VERSION
17 #error This file was generated by an older version of protoc which is
18 #error incompatible with your Protocol Buffer headers. Please
19 #error regenerate this file with a newer version of protoc.
20 #endif
21
22 #include <google/protobuf/port_undef.inc>
23 #include <google/protobuf/io/coded_stream.h>
24 #include <google/protobuf/arena.h>
25 #include <google/protobuf/arenastring.h>
26 #include <google/protobuf/generated_message_util.h>
27 #include <google/protobuf/metadata_lite.h>
28 #include <google/protobuf/generated_message_reflection.h>
29 #include <google/protobuf/message.h>
30 #include <google/protobuf/repeated_field.h> // IWYU pragma: export
31 #include <google/protobuf/extension_set.h> // IWYU pragma: export
32 #include <google/protobuf/generated_enum_reflection.h>

```

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```

33 #include <google/protobuf/unknown_field_set.h>
34 // @@protoc_insertion_point(includes)
35 #include <google/protobuf/port_def.inc>
36 #define PROTOBUF_INTERNAL_EXPORT_hello_2eproto
37 PROTOBUF_NAMESPACE_OPEN
38 namespace internal {
39 class AnyMetadata;
40 } // namespace internal
41 PROTOBUF_NAMESPACE_CLOSE
42
43 // Internal implementation detail -- do not use these members.
44 struct TableStruct_hello_2eproto {
45     static const uint32_t offsets[];
46 };
47 extern const ::PROTOBUF_NAMESPACE_ID::internal::DescriptorTable descriptor_table_hello_
48 ↪ 2eproto;
49 namespace tutorial {
50 class AddressBook;
51 struct AddressBookDefaultTypeInternal;
52 extern AddressBookDefaultTypeInternal _AddressBook_default_instance_;
53 class Person;
54 struct PersonDefaultTypeInternal;
55 extern PersonDefaultTypeInternal _Person_default_instance_;
56 class Person_PhoneNumber;
57 struct Person_PhoneNumberDefaultTypeInternal;
58 extern Person_PhoneNumberDefaultTypeInternal _Person_PhoneNumber_default_instance_;
59 } // namespace tutorial
60 PROTOBUF_NAMESPACE_OPEN
61 template<> ::tutorial::AddressBook* Arena::CreateMaybeMessage<::tutorial::AddressBook>
62 ↪ (Arena*);
63 template<> ::tutorial::Person* Arena::CreateMaybeMessage<::tutorial::Person>(Arena*);
64 template<> ::tutorial::Person_PhoneNumber* Arena::CreateMaybeMessage<::tutorial::Person_
65 ↪ PhoneNumber>(Arena*);
66 PROTOBUF_NAMESPACE_CLOSE
67 namespace tutorial {
68
69 enum Person_PhoneType : int {
70     Person_PhoneType_MOBILE = 0,
71     Person_PhoneType_HOME = 1,
72     Person_PhoneType_WORK = 2
73 };
74 bool Person_PhoneType_IsValid(int value);
75 constexpr Person_PhoneType Person_PhoneType_PhoneType_MIN = Person_PhoneType_MOBILE;
76 constexpr Person_PhoneType Person_PhoneType_PhoneType_MAX = Person_PhoneType_WORK;
77 constexpr int Person_PhoneType_PhoneType_ARRAYSIZE = Person_PhoneType_PhoneType_MAX + 1;
78
79 const ::PROTOBUF_NAMESPACE_ID::EnumDescriptor* Person_PhoneType_descriptor();
80 template<typename T>
81 inline const std::string& Person_PhoneType_Name(T enum_t_value) {
82     static_assert(::std::is_same<T, Person_PhoneType>::value ||
83         ::std::is_integral<T>::value,
84         "Incorrect type passed to function Person_PhoneType_Name.");

```

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```

82     return ::PROTOBUF_NAMESPACE_ID::internal::NameOfEnum(
83         Person_PhoneType_descriptor(), enum_t_value);
84 }
85 inline bool Person_PhoneType_Parse(
86     ::PROTOBUF_NAMESPACE_ID::ConstStringParam name, Person_PhoneType* value) {
87     return ::PROTOBUF_NAMESPACE_ID::internal::ParseNamedEnum<Person_PhoneType>(
88         Person_PhoneType_descriptor(), name, value);
89 }
90 // =====
91
92 class Person_PhoneNumber final :
93     public ::PROTOBUF_NAMESPACE_ID::Message /* @@protoc_insertion_point(class_
94     ↳definition:tutorial.Person.PhoneNumber) */ {
95 public:
96     inline Person_PhoneNumber() : Person_PhoneNumber(nullptr) {}
97     ~Person_PhoneNumber() override;
98     explicit PROTOBUF_CONSTEXPR Person_PhoneNumber(::PROTOBUF_NAMESPACE_ID::
99     ↳ID::internal::ConstantInitialized);
100
101     Person_PhoneNumber(const Person_PhoneNumber& from);
102     Person_PhoneNumber(Person_PhoneNumber&& from) noexcept
103         : Person_PhoneNumber() {
104         *this = ::std::move(from);
105     }
106
107     inline Person_PhoneNumber& operator=(const Person_PhoneNumber& from) {
108         CopyFrom(from);
109         return *this;
110     }
111
112     inline Person_PhoneNumber& operator=(Person_PhoneNumber&& from) noexcept {
113         if (this == &from) return *this;
114         if (GetOwningArena() == from.GetOwningArena()
115         #ifdef PROTOBUF_FORCE_COPY_IN_MOVE
116             && GetOwningArena() != nullptr
117         #endif // !PROTOBUF_FORCE_COPY_IN_MOVE
118         ) {
119             InternalSwap(&from);
120         } else {
121             CopyFrom(from);
122         }
123         return *this;
124     }
125
126     inline const ::PROTOBUF_NAMESPACE_ID::UnknownFieldSet& unknown_fields() const {
127         return _internal_metadata_.unknown_fields<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>
128         ↳ (::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance);
129     }
130
131     inline ::PROTOBUF_NAMESPACE_ID::UnknownFieldSet* mutable_unknown_fields() {
132         return _internal_metadata_.mutable_unknown_fields<::PROTOBUF_NAMESPACE_ID::
133         ↳ID::UnknownFieldSet>();
134     }

```

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```

130 static const ::PROTOBUF_NAMESPACE_ID::Descriptor* descriptor() {
131     return GetDescriptor();
132 }
133 static const ::PROTOBUF_NAMESPACE_ID::Descriptor* GetDescriptor() {
134     return default_instance().GetMetadata().descriptor;
135 }
136 static const ::PROTOBUF_NAMESPACE_ID::Reflection* GetReflection() {
137     return default_instance().GetMetadata().reflection;
138 }
139 static const Person_PhoneNumber& default_instance() {
140     return *internal_default_instance();
141 }
142 static inline const Person_PhoneNumber* internal_default_instance() {
143     return reinterpret_cast<const Person_PhoneNumber*>(
144         &_Person_PhoneNumber_default_instance_);
145 }
146 static constexpr int kIndexInFileMessages =
147     0;
148
149 friend void swap(Person_PhoneNumber& a, Person_PhoneNumber& b) {
150     a.Swap(&b);
151 }
152 inline void Swap(Person_PhoneNumber* other) {
153     if (other == this) return;
154 #ifdef PROTOBUF_FORCE_COPY_IN_SWAP
155     if (GetOwningArena() != nullptr &&
156         GetOwningArena() == other->GetOwningArena()) {
157         #else // PROTOBUF_FORCE_COPY_IN_SWAP
158         if (GetOwningArena() == other->GetOwningArena()) {
159         #endif // !PROTOBUF_FORCE_COPY_IN_SWAP
160             InternalSwap(other);
161         } else {
162             ::PROTOBUF_NAMESPACE_ID::internal::GenericSwap(this, other);
163         }
164     }
165 void UnsafeArenaSwap(Person_PhoneNumber* other) {
166     if (other == this) return;
167     GOOGLE_DCHECK(GetOwningArena() == other->GetOwningArena());
168     InternalSwap(other);
169 }
170
171 // implements Message -----
172
173 Person_PhoneNumber* New(::PROTOBUF_NAMESPACE_ID::Arena* arena = nullptr) const final {
174     return CreateMaybeMessage<Person_PhoneNumber>(arena);
175 }
176 using ::PROTOBUF_NAMESPACE_ID::Message::CopyFrom;
177 void CopyFrom(const Person_PhoneNumber& from);
178 using ::PROTOBUF_NAMESPACE_ID::Message::MergeFrom;
179 void MergeFrom(const Person_PhoneNumber& from);
180 private:
181 static void MergeImpl(::PROTOBUF_NAMESPACE_ID::Message* to, const ::PROTOBUF_NAMESPACE_
    ID::Message& from);

```

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```

182 public:
183   PROTOBUF_ATTRIBUTE_REINITIALIZES void Clear() final;
184   bool IsInitialized() const final;
185
186   size_t ByteSizeLong() const final;
187   const char* _InternalParse(const char* ptr, ::PROTOBUF_NAMESPACE_
↪ ID::internal::ParseContext* ctx) final;
188   uint8_t* _InternalSerialize(
189     uint8_t* target, ::PROTOBUF_NAMESPACE_ID::io::EpsCopyOutputStream* stream) const_
↪ final;
190   int GetCachedSize() const final { return _cached_size_.Get(); }
191
192 private:
193   void SharedCtor();
194   void SharedDtor();
195   void SetCachedSize(int size) const final;
196   void InternalSwap(Person_PhoneNumber* other);
197
198 private:
199   friend class ::PROTOBUF_NAMESPACE_ID::internal::AnyMetadata;
200   static ::PROTOBUF_NAMESPACE_ID::StringPiece FullMessageName() {
201     return "tutorial.Person.PhoneNumber";
202   }
203 protected:
204   explicit Person_PhoneNumber(::PROTOBUF_NAMESPACE_ID::Arena* arena,
205     bool is_message_owned = false);
206 public:
207
208   static const ClassData _class_data_;
209   const ::PROTOBUF_NAMESPACE_ID::Message::ClassData* GetClassData() const final;
210
211   ::PROTOBUF_NAMESPACE_ID::Metadata GetMetadata() const final;
212
213   // nested types -----
214
215   // accessors -----
216
217   enum : int {
218     kNumberFieldName = 1,
219     kTypeFieldName = 2,
220   };
221   // optional string number = 1;
222   bool has_number() const;
223 private:
224   bool _internal_has_number() const;
225 public:
226   void clear_number();
227   const std::string& number() const;
228   template <typename ArgT0 = const std::string&, typename... ArgT>
229   void set_number(ArgT0&& arg0, ArgT... args);
230   std::string* mutable_number();
231   PROTOBUF_NODISCARD std::string* release_number();

```

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```

232 void set_allocated_number(std::string* number);
233 private:
234 const std::string& _internal_number() const;
235 inline PROTOBUF_ALWAYS_INLINE void _internal_set_number(const std::string& value);
236 std::string* _internal_mutable_number();
237 public:
238
239 // optional .tutorial.Person.PhoneType type = 2 [default = HOME];
240 bool has_type() const;
241 private:
242 bool _internal_has_type() const;
243 public:
244 void clear_type();
245 ::tutorial::Person_PhoneType type() const;
246 void set_type(::tutorial::Person_PhoneType value);
247 private:
248 ::tutorial::Person_PhoneType _internal_type() const;
249 void _internal_set_type(::tutorial::Person_PhoneType value);
250 public:
251
252 // @@protoc_insertion_point(class_scope:tutorial.Person.PhoneNumber)
253 private:
254 class _Internal;
255
256 template <typename T> friend class ::PROTOBUF_NAMESPACE_ID::Arena::InternalHelper;
257 typedef void InternalArenaConstructable_;
258 typedef void DestructorSkippable_;
259 ::PROTOBUF_NAMESPACE_ID::internal::HasBits<1> _has_bits_;
260 mutable ::PROTOBUF_NAMESPACE_ID::internal::CachedSize _cached_size_;
261 ::PROTOBUF_NAMESPACE_ID::internal::ArenaStringPtr number_;
262 int type_;
263 friend struct ::TableStruct_hello_2eproto;
264 };
265 // -----
266
267 class Person final :
268   public ::PROTOBUF_NAMESPACE_ID::Message /* @@protoc_insertion_point(class_
↳ definition:tutorial.Person) */ {
269 public:
270   inline Person() : Person(nullptr) {}
271   ~Person() override;
272   explicit PROTOBUF_CONSTEXPR Person(::PROTOBUF_NAMESPACE_
↳ ID::internal::ConstantInitialized);
273
274   Person(const Person& from);
275   Person(Person&& from) noexcept
276     : Person() {
277     *this = ::std::move(from);
278   }
279
280   inline Person& operator=(const Person& from) {
281     CopyFrom(from);

```

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```

282     return *this;
283 }
284 inline Person& operator=(Person&& from) noexcept {
285     if (this == &from) return *this;
286     if (GetOwningArena() == from.GetOwningArena()
287 #ifdef PROTOBUF_FORCE_COPY_IN_MOVE
288         && GetOwningArena() != nullptr
289 #endif // !PROTOBUF_FORCE_COPY_IN_MOVE
290     ) {
291         InternalSwap(&from);
292     } else {
293         CopyFrom(from);
294     }
295     return *this;
296 }
297
298 inline const ::PROTOBUF_NAMESPACE_ID::UnknownFieldSet& unknown_fields() const {
299     return _internal_metadata_.unknown_fields<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>
300     ↪ (::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance);
301 }
302 inline ::PROTOBUF_NAMESPACE_ID::UnknownFieldSet* mutable_unknown_fields() {
303     return _internal_metadata_.mutable_unknown_fields<::PROTOBUF_NAMESPACE_
304     ↪ ID::UnknownFieldSet>();
305 }
306
307 static const ::PROTOBUF_NAMESPACE_ID::Descriptor* descriptor() {
308     return GetDescriptor();
309 }
310 static const ::PROTOBUF_NAMESPACE_ID::Descriptor* GetDescriptor() {
311     return default_instance().GetMetadata().descriptor;
312 }
313 static const ::PROTOBUF_NAMESPACE_ID::Reflection* GetReflection() {
314     return default_instance().GetMetadata().reflection;
315 }
316 static const Person& default_instance() {
317     return *internal_default_instance();
318 }
319 static inline const Person* internal_default_instance() {
320     return reinterpret_cast<const Person*>(
321         &_Person_default_instance_);
322 }
323
324 static constexpr int kIndexInFileMessages =
325     1;
326
327 friend void swap(Person& a, Person& b) {
328     a.Swap(&b);
329 }
330 inline void Swap(Person* other) {
331     if (other == this) return;
332 #ifdef PROTOBUF_FORCE_COPY_IN_SWAP
333     if (GetOwningArena() != nullptr &&
334         GetOwningArena() == other->GetOwningArena()) {

```

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```

332     #else // PROTOBUF_FORCE_COPY_IN_SWAP
333         if (GetOwningArena() == other->GetOwningArena()) {
334     #endif // !PROTOBUF_FORCE_COPY_IN_SWAP
335         InternalSwap(other);
336     } else {
337         ::PROTOBUF_NAMESPACE_ID::internal::GenericSwap(this, other);
338     }
339 }
340 void UnsafeArenaSwap(Person* other) {
341     if (other == this) return;
342     GOOGLE_DCHECK(GetOwningArena() == other->GetOwningArena());
343     InternalSwap(other);
344 }
345
346 // implements Message -----
347
348 Person* New(::PROTOBUF_NAMESPACE_ID::Arena* arena = nullptr) const final {
349     return CreateMaybeMessage<Person>(arena);
350 }
351 using ::PROTOBUF_NAMESPACE_ID::Message::CopyFrom;
352 void CopyFrom(const Person& from);
353 using ::PROTOBUF_NAMESPACE_ID::Message::MergeFrom;
354 void MergeFrom(const Person& from);
355 private:
356 static void MergeImpl(::PROTOBUF_NAMESPACE_ID::Message* to, const ::PROTOBUF_NAMESPACE_
↵ ID::Message& from);
357 public:
358 PROTOBUF_ATTRIBUTE_REINITIALIZES void Clear() final;
359 bool IsInitialized() const final;
360
361 size_t ByteSizeLong() const final;
362 const char* _InternalParse(const char* ptr, ::PROTOBUF_NAMESPACE_
↵ ID::internal::ParseContext* ctx) final;
363 uint8_t* _InternalSerialize(
364     uint8_t* target, ::PROTOBUF_NAMESPACE_ID::io::EpsCopyOutputStream* stream) const,
↵ final;
365 int GetCachedSize() const final { return _cached_size_.Get(); }
366
367 private:
368 void SharedCtor();
369 void SharedDtor();
370 void SetCachedSize(int size) const final;
371 void InternalSwap(Person* other);
372
373 private:
374 friend class ::PROTOBUF_NAMESPACE_ID::internal::AnyMetadata;
375 static ::PROTOBUF_NAMESPACE_ID::StringPiece FullMessageName() {
376     return "tutorial.Person";
377 }
378 protected:
379 explicit Person(::PROTOBUF_NAMESPACE_ID::Arena* arena,
380                 bool is_message_owned = false);

```

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```

381 public:
382
383 static const ClassData _class_data_;
384 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData*GetClassData() const final;
385
386 ::PROTOBUF_NAMESPACE_ID::Metadata GetMetadata() const final;
387
388 // nested types -----
389
390 typedef Person_PhoneNumber PhoneNumber;
391
392 typedef Person_PhoneType PhoneType;
393 static constexpr PhoneType MOBILE =
394     Person_PhoneType_MOBILE;
395 static constexpr PhoneType HOME =
396     Person_PhoneType_HOME;
397 static constexpr PhoneType WORK =
398     Person_PhoneType_WORK;
399 static inline bool PhoneType_IsValid(int value) {
400     return Person_PhoneType_IsValid(value);
401 }
402 static constexpr PhoneType PhoneType_MIN =
403     Person_PhoneType_PhoneType_MIN;
404 static constexpr PhoneType PhoneType_MAX =
405     Person_PhoneType_PhoneType_MAX;
406 static constexpr int PhoneType_ARRAYSIZE =
407     Person_PhoneType_PhoneType_ARRAYSIZE;
408 static inline const ::PROTOBUF_NAMESPACE_ID::EnumDescriptor*
409 PhoneType_descriptor() {
410     return Person_PhoneType_descriptor();
411 }
412 template<typename T>
413 static inline const std::string& PhoneType_Name(T enum_t_value) {
414     static_assert(::std::is_same<T, PhoneType>::value ||
415         ::std::is_integral<T>::value,
416         "Incorrect type passed to function PhoneType_Name.");
417     return Person_PhoneType_Name(enum_t_value);
418 }
419 static inline bool PhoneType_Parse(::PROTOBUF_NAMESPACE_ID::ConstStringParam name,
420     PhoneType* value) {
421     return Person_PhoneType_Parse(name, value);
422 }
423
424 // accessors -----
425
426 enum : int {
427     kPhonesFieldNumber = 4,
428     kNameFieldNumber = 1,
429     kEmailFieldNumber = 3,
430     kIdFieldNumber = 2,
431 };
432 // repeated .tutorial.Person.PhoneNumber phones = 4;

```

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```

433     int phones_size() const;
434 private:
435     int _internal_phones_size() const;
436 public:
437     void clear_phones();
438     ::tutorial::Person_PhoneNumber* mutable_phones(int index);
439     ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person_PhoneNumber >*
440         mutable_phones();
441 private:
442     const ::tutorial::Person_PhoneNumber& _internal_phones(int index) const;
443     ::tutorial::Person_PhoneNumber* _internal_add_phones();
444 public:
445     const ::tutorial::Person_PhoneNumber& phones(int index) const;
446     ::tutorial::Person_PhoneNumber* add_phones();
447     const ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person_PhoneNumber >&
448         phones() const;
449
450     // optional string name = 1;
451     bool has_name() const;
452 private:
453     bool _internal_has_name() const;
454 public:
455     void clear_name();
456     const std::string& name() const;
457     template <typename ArgT0 = const std::string&, typename... ArgT>
458     void set_name(ArgT0&& arg0, ArgT... args);
459     std::string* mutable_name();
460     PROTOBUF_NODISCARD std::string* release_name();
461     void set_allocated_name(std::string* name);
462 private:
463     const std::string& _internal_name() const;
464     inline PROTOBUF_ALWAYS_INLINE void _internal_set_name(const std::string& value);
465     std::string* _internal_mutable_name();
466 public:
467
468     // optional string email = 3;
469     bool has_email() const;
470 private:
471     bool _internal_has_email() const;
472 public:
473     void clear_email();
474     const std::string& email() const;
475     template <typename ArgT0 = const std::string&, typename... ArgT>
476     void set_email(ArgT0&& arg0, ArgT... args);
477     std::string* mutable_email();
478     PROTOBUF_NODISCARD std::string* release_email();
479     void set_allocated_email(std::string* email);
480 private:
481     const std::string& _internal_email() const;
482     inline PROTOBUF_ALWAYS_INLINE void _internal_set_email(const std::string& value);
483     std::string* _internal_mutable_email();
484 public:

```

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```

485 // optional int32 id = 2;
486 bool has_id() const;
487 private:
488 bool _internal_has_id() const;
489 public:
490 void clear_id();
491 int32_t id() const;
492 void set_id(int32_t value);
493 private:
494 int32_t _internal_id() const;
495 void _internal_set_id(int32_t value);
496 public:
497
498 // @@protoc_insertion_point(class_scope:tutorial.Person)
499 private:
500 class _Internal;
501
502 template <typename T> friend class ::PROTOBUF_NAMESPACE_ID::Arena::InternalHelper;
503 typedef void InternalArenaConstructable_;
504 typedef void DestructorSkippable_;
505 ::PROTOBUF_NAMESPACE_ID::internal::HasBits<1> _has_bits_;
506 mutable ::PROTOBUF_NAMESPACE_ID::internal::CachedSize _cached_size_;
507 ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person_PhoneNumber > phones_;
508 ::PROTOBUF_NAMESPACE_ID::internal::ArenaStringPtr name_;
509 ::PROTOBUF_NAMESPACE_ID::internal::ArenaStringPtr email_;
510 int32_t id_;
511 friend struct ::TableStruct_hello_2eproto;
512 };
513 // -----
514
515 class AddressBook final :
516     public ::PROTOBUF_NAMESPACE_ID::Message /* @@protoc_insertion_point(class_
↳ definition:tutorial.AddressBook) */ {
517 public:
518     inline AddressBook() : AddressBook(nullptr) {}
519     ~AddressBook() override;
520     explicit PROTOBUF_CONSTEXPR AddressBook(::PROTOBUF_NAMESPACE_ID::internal::ConstantInitialized);
521     ↳ ID::internal::ConstantInitialized);
522
523     AddressBook(const AddressBook& from);
524     AddressBook(AddressBook&& from) noexcept
525         : AddressBook() {
526         *this = ::std::move(from);
527     }
528
529     inline AddressBook& operator=(const AddressBook& from) {
530         CopyFrom(from);
531         return *this;
532     }
533     inline AddressBook& operator=(AddressBook&& from) noexcept {
534         if (this == &from) return *this;

```

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```

535     if (GetOwningArena() == from.GetOwningArena()
536 #ifdef PROTOBUF_FORCE_COPY_IN_MOVE
537         && GetOwningArena() != nullptr
538 #endif // !PROTOBUF_FORCE_COPY_IN_MOVE
539     ) {
540         InternalSwap(&from);
541     } else {
542         CopyFrom(from);
543     }
544     return *this;
545 }
546
547 inline const ::PROTOBUF_NAMESPACE_ID::UnknownFieldSet& unknown_fields() const {
548     return _internal_metadata_.unknown_fields<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>
549 ↪ (::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance());
550 }
551 inline ::PROTOBUF_NAMESPACE_ID::UnknownFieldSet* mutable_unknown_fields() {
552     return _internal_metadata_.mutable_unknown_fields<::PROTOBUF_NAMESPACE_
553 ↪ ID::UnknownFieldSet>();
554 }
555
556 static const ::PROTOBUF_NAMESPACE_ID::Descriptor* descriptor() {
557     return GetDescriptor();
558 }
559 static const ::PROTOBUF_NAMESPACE_ID::Descriptor* GetDescriptor() {
560     return default_instance().GetMetadata().descriptor;
561 }
562 static const ::PROTOBUF_NAMESPACE_ID::Reflection* GetReflection() {
563     return default_instance().GetMetadata().reflection;
564 }
565 static const AddressBook& default_instance() {
566     return *internal_default_instance();
567 }
568 static inline const AddressBook* internal_default_instance() {
569     return reinterpret_cast<const AddressBook*>(
570         &_AddressBook_default_instance_);
571 }
572 static constexpr int kIndexInFileMessages =
573     2;
574
575 friend void swap(AddressBook& a, AddressBook& b) {
576     a.Swap(&b);
577 }
578 inline void Swap(AddressBook* other) {
579     if (other == this) return;
580 #ifdef PROTOBUF_FORCE_COPY_IN_SWAP
581     if (GetOwningArena() != nullptr &&
582         GetOwningArena() == other->GetOwningArena()) {
583 #else // PROTOBUF_FORCE_COPY_IN_SWAP
584     if (GetOwningArena() == other->GetOwningArena()) {
585 #endif // !PROTOBUF_FORCE_COPY_IN_SWAP
586         InternalSwap(other);

```

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```

585     } else {
586         ::PROTOBUF_NAMESPACE_ID::internal::GenericSwap(this, other);
587     }
588 }
589 void UnsafeArenaSwap(AddressBook* other) {
590     if (other == this) return;
591     GOOGLE_DCHECK(GetOwningArena() == other->GetOwningArena());
592     InternalSwap(other);
593 }
594
595 // implements Message -----
596
597 AddressBook* New(::PROTOBUF_NAMESPACE_ID::Arena* arena = nullptr) const final {
598     return CreateMaybeMessage<AddressBook>(arena);
599 }
600 using ::PROTOBUF_NAMESPACE_ID::Message::CopyFrom;
601 void CopyFrom(const AddressBook& from);
602 using ::PROTOBUF_NAMESPACE_ID::Message::MergeFrom;
603 void MergeFrom(const AddressBook& from);
604 private:
605 static void MergeImpl(::PROTOBUF_NAMESPACE_ID::Message* to, const ::PROTOBUF_NAMESPACE_ID::Message& from);
606 public:
607 PROTOBUF_ATTRIBUTE_REINITIALIZES void Clear() final;
608 bool IsInitialized() const final;
609
610 size_t ByteSizeLong() const final;
611 const char* _InternalParse(const char* ptr, ::PROTOBUF_NAMESPACE_ID::internal::ParseContext* ctx) final;
612 uint8_t* _InternalSerialize(
613     uint8_t* target, ::PROTOBUF_NAMESPACE_ID::io::EpsCopyOutputStream* stream) const final;
614 int GetCachedSize() const final { return _cached_size_.Get(); }
615
616 private:
617 void SharedCtor();
618 void SharedDtor();
619 void SetCachedSize(int size) const final;
620 void InternalSwap(AddressBook* other);
621
622 private:
623 friend class ::PROTOBUF_NAMESPACE_ID::internal::AnyMetadata;
624 static ::PROTOBUF_NAMESPACE_ID::StringPiece FullMessageName() {
625     return "tutorial.AddressBook";
626 }
627 protected:
628 explicit AddressBook(::PROTOBUF_NAMESPACE_ID::Arena* arena,
629                     bool is_message_owned = false);
630 public:
631
632 static const ClassData _class_data_;
633 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData* GetClassData() const final;

```

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```

634
635 ::PROTOBUF_NAMESPACE_ID::Metadata GetMetadata() const final;
636
637 // nested types -----
638
639 // accessors -----
640
641 enum : int {
642     kPeopleFieldName = 1,
643 };
644 // repeated .tutorial.Person people = 1;
645 int people_size() const;
646 private:
647 int _internal_people_size() const;
648 public:
649 void clear_people();
650 ::tutorial::Person* mutable_people(int index);
651 ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person >*
652     mutable_people();
653 private:
654 const ::tutorial::Person& _internal_people(int index) const;
655 ::tutorial::Person* _internal_add_people();
656 public:
657 const ::tutorial::Person& people(int index) const;
658 ::tutorial::Person* add_people();
659 const ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person >&
660     people() const;
661
662 // @@protoc_insertion_point(class_scope:tutorial.AddressBook)
663 private:
664 class _Internal;
665
666 template <typename T> friend class ::PROTOBUF_NAMESPACE_ID::Arena::InternalHelper;
667 typedef void InternalArenaConstructable_;
668 typedef void DestructorSkippable_;
669 ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person > people_;
670 mutable ::PROTOBUF_NAMESPACE_ID::internal::CachedSize _cached_size_;
671 friend struct ::TableStruct_hello_2eproto;
672 };
673 // =====
674
675 // =====
676
677 #ifndef __GNUC__
678     #pragma GCC diagnostic push
679     #pragma GCC diagnostic ignored "-Wstrict-aliasing"
680 #endif // __GNUC__
681 // Person_PhoneNumber
682
683
684 // optional string number = 1;
685 inline bool Person_PhoneNumber::_internal_has_number() const {

```

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```

686     bool value = (_has_bits_[0] & 0x00000001u) != 0;
687     return value;
688 }
689 inline bool Person_PhoneNumber::has_number() const {
690     return _internal_has_number();
691 }
692 inline void Person_PhoneNumber::clear_number() {
693     number_.ClearToEmpty();
694     _has_bits_[0] &= ~0x00000001u;
695 }
696 inline const std::string& Person_PhoneNumber::number() const {
697     // @@protoc_insertion_point(field_get:tutorial.Person.PhoneNumber.number)
698     return _internal_number();
699 }
700 template <typename ArgT0, typename... ArgT>
701 inline PROTOBUF_ALWAYS_INLINE
702 void Person_PhoneNumber::set_number(ArgT0&& arg0, ArgT... args) {
703     _has_bits_[0] |= 0x00000001u;
704     number_.Set(static_cast<ArgT0 &&>(arg0), args..., GetArenaForAllocation());
705     // @@protoc_insertion_point(field_set:tutorial.Person.PhoneNumber.number)
706 }
707 inline std::string* Person_PhoneNumber::mutable_number() {
708     std::string* _s = _internal_mutable_number();
709     // @@protoc_insertion_point(field_mutable:tutorial.Person.PhoneNumber.number)
710     return _s;
711 }
712 inline const std::string& Person_PhoneNumber::_internal_number() const {
713     return number_.Get();
714 }
715 inline void Person_PhoneNumber::_internal_set_number(const std::string& value) {
716     _has_bits_[0] |= 0x00000001u;
717     number_.Set(value, GetArenaForAllocation());
718 }
719 inline std::string* Person_PhoneNumber::_internal_mutable_number() {
720     _has_bits_[0] |= 0x00000001u;
721     return number_.Mutable(GetArenaForAllocation());
722 }
723 inline std::string* Person_PhoneNumber::release_number() {
724     // @@protoc_insertion_point(field_release:tutorial.Person.PhoneNumber.number)
725     if (!_internal_has_number()) {
726         return nullptr;
727     }
728     _has_bits_[0] &= ~0x00000001u;
729     auto* p = number_.Release();
730 #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
731     if (number_.IsDefault()) {
732         number_.Set("", GetArenaForAllocation());
733     }
734 #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
735     return p;
736 }
737 inline void Person_PhoneNumber::set_allocated_number(std::string* number) {

```

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```

738     if (number != nullptr) {
739         _has_bits_[0] |= 0x000000001u;
740     } else {
741         _has_bits_[0] &= ~0x000000001u;
742     }
743     number_.SetAllocated(number, GetArenaForAllocation());
744 #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
745     if (number_.IsDefault()) {
746         number_.Set("", GetArenaForAllocation());
747     }
748 #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
749     // @@protoc_insertion_point(field_set_allocated:tutorial.Person.PhoneNumber.number)
750 }
751
752 // optional .tutorial.Person.PhoneType type = 2 [default = HOME];
753 inline bool Person_PhoneNumber::_internal_has_type() const {
754     bool value = (_has_bits_[0] & 0x000000002u) != 0;
755     return value;
756 }
757 inline bool Person_PhoneNumber::has_type() const {
758     return _internal_has_type();
759 }
760 inline void Person_PhoneNumber::clear_type() {
761     type_ = 1;
762     _has_bits_[0] &= ~0x000000002u;
763 }
764 inline ::tutorial::Person_PhoneType Person_PhoneNumber::_internal_type() const {
765     return static_cast< ::tutorial::Person_PhoneType >(type_);
766 }
767 inline ::tutorial::Person_PhoneType Person_PhoneNumber::type() const {
768     // @@protoc_insertion_point(field_get:tutorial.Person.PhoneNumber.type)
769     return _internal_type();
770 }
771 inline void Person_PhoneNumber::_internal_set_type(::tutorial::Person_PhoneType value) {
772     assert(::tutorial::Person_PhoneType_IsValid(value));
773     _has_bits_[0] |= 0x000000002u;
774     type_ = value;
775 }
776 inline void Person_PhoneNumber::set_type(::tutorial::Person_PhoneType value) {
777     _internal_set_type(value);
778     // @@protoc_insertion_point(field_set:tutorial.Person.PhoneNumber.type)
779 }
780
781 // -----
782
783 // Person
784
785 // optional string name = 1;
786 inline bool Person::_internal_has_name() const {
787     bool value = (_has_bits_[0] & 0x000000001u) != 0;
788     return value;
789 }

```

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```

790 inline bool Person::has_name() const {
791     return _internal_has_name();
792 }
793 inline void Person::clear_name() {
794     name_.ClearToEmpty();
795     _has_bits_[0] &= ~0x00000001u;
796 }
797 inline const std::string& Person::name() const {
798     // @@protoc_insertion_point(field_get:tutorial.Person.name)
799     return _internal_name();
800 }
801 template <typename ArgT0, typename... ArgT>
802 inline PROTOBUF_ALWAYS_INLINE
803 void Person::set_name(ArgT0&& arg0, ArgT... args) {
804     _has_bits_[0] |= 0x00000001u;
805     name_.Set(static_cast<ArgT0 &&>(arg0), args..., GetArenaForAllocation());
806     // @@protoc_insertion_point(field_set:tutorial.Person.name)
807 }
808 inline std::string* Person::mutable_name() {
809     std::string* _s = _internal_mutable_name();
810     // @@protoc_insertion_point(field_mutable:tutorial.Person.name)
811     return _s;
812 }
813 inline const std::string& Person::_internal_name() const {
814     return name_.Get();
815 }
816 inline void Person::_internal_set_name(const std::string& value) {
817     _has_bits_[0] |= 0x00000001u;
818     name_.Set(value, GetArenaForAllocation());
819 }
820 inline std::string* Person::_internal_mutable_name() {
821     _has_bits_[0] |= 0x00000001u;
822     return name_.Mutable(GetArenaForAllocation());
823 }
824 inline std::string* Person::release_name() {
825     // @@protoc_insertion_point(field_release:tutorial.Person.name)
826     if (!_internal_has_name()) {
827         return nullptr;
828     }
829     _has_bits_[0] &= ~0x00000001u;
830     auto* p = name_.Release();
831 #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
832     if (name_.IsDefault()) {
833         name_.Set("", GetArenaForAllocation());
834     }
835 #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
836     return p;
837 }
838 inline void Person::set_allocated_name(std::string* name) {
839     if (name != nullptr) {
840         _has_bits_[0] |= 0x00000001u;
841     } else {

```

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```

842     _has_bits_[0] &= ~0x00000001u;
843 }
844 name_.SetAllocated(name, GetArenaForAllocation());
845 #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
846     if (name_.IsDefault()) {
847         name_.Set("", GetArenaForAllocation());
848     }
849 #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
850     // @@protoc_insertion_point(field_set_allocated:tutorial.Person.name)
851 }
852
853 // optional int32 id = 2;
854 inline bool Person::_internal_has_id() const {
855     bool value = (_has_bits_[0] & 0x00000004u) != 0;
856     return value;
857 }
858 inline bool Person::has_id() const {
859     return _internal_has_id();
860 }
861 inline void Person::clear_id() {
862     id_ = 0;
863     _has_bits_[0] &= ~0x00000004u;
864 }
865 inline int32_t Person::_internal_id() const {
866     return id_;
867 }
868 inline int32_t Person::id() const {
869     // @@protoc_insertion_point(field_get:tutorial.Person.id)
870     return _internal_id();
871 }
872 inline void Person::_internal_set_id(int32_t value) {
873     _has_bits_[0] |= 0x00000004u;
874     id_ = value;
875 }
876 inline void Person::set_id(int32_t value) {
877     _internal_set_id(value);
878     // @@protoc_insertion_point(field_set:tutorial.Person.id)
879 }
880
881 // optional string email = 3;
882 inline bool Person::_internal_has_email() const {
883     bool value = (_has_bits_[0] & 0x00000002u) != 0;
884     return value;
885 }
886 inline bool Person::has_email() const {
887     return _internal_has_email();
888 }
889 inline void Person::clear_email() {
890     email_.ClearToEmpty();
891     _has_bits_[0] &= ~0x00000002u;
892 }
893 inline const std::string& Person::email() const {

```

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```

894 // @@protoc_insertion_point(field_get:tutorial.Person.email)
895 return _internal_email();
896 }
897 template <typename ArgT0, typename... ArgT>
898 inline PROTOBUF_ALWAYS_INLINE
899 void Person::set_email(ArgT0&& arg0, ArgT... args) {
900   _has_bits_[0] |= 0x000000002u;
901   email_.Set(static_cast<ArgT0 &&>(arg0), args..., GetArenaForAllocation());
902   // @@protoc_insertion_point(field_set:tutorial.Person.email)
903 }
904 inline std::string* Person::mutable_email() {
905   std::string* _s = _internal_mutable_email();
906   // @@protoc_insertion_point(field_mutable:tutorial.Person.email)
907   return _s;
908 }
909 inline const std::string& Person::_internal_email() const {
910   return email_.Get();
911 }
912 inline void Person::_internal_set_email(const std::string& value) {
913   _has_bits_[0] |= 0x000000002u;
914   email_.Set(value, GetArenaForAllocation());
915 }
916 inline std::string* Person::_internal_mutable_email() {
917   _has_bits_[0] |= 0x000000002u;
918   return email_.Mutable(GetArenaForAllocation());
919 }
920 inline std::string* Person::release_email() {
921   // @@protoc_insertion_point(field_release:tutorial.Person.email)
922   if (!_internal_has_email()) {
923     return nullptr;
924   }
925   _has_bits_[0] &= ~0x000000002u;
926   auto* p = email_.Release();
927 #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
928   if (email_.IsDefault()) {
929     email_.Set("", GetArenaForAllocation());
930   }
931 #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
932   return p;
933 }
934 inline void Person::set_allocated_email(std::string* email) {
935   if (email != nullptr) {
936     _has_bits_[0] |= 0x000000002u;
937   } else {
938     _has_bits_[0] &= ~0x000000002u;
939   }
940   email_.SetAllocated(email, GetArenaForAllocation());
941 #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
942   if (email_.IsDefault()) {
943     email_.Set("", GetArenaForAllocation());
944   }
945 #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING

```

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```

946 // @@protoc_insertion_point(field_set_allocated:tutorial.Person.email)
947 }
948
949 // repeated .tutorial.Person.PhoneNumber phones = 4;
950 inline int Person::_internal_phones_size() const {
951     return phones_.size();
952 }
953 inline int Person::phones_size() const {
954     return _internal_phones_size();
955 }
956 inline void Person::clear_phones() {
957     phones_.Clear();
958 }
959 inline ::tutorial::Person_PhoneNumber* Person::mutable_phones(int index) {
960     // @@protoc_insertion_point(field_mutable:tutorial.Person.phones)
961     return phones_.Mutable(index);
962 }
963 inline ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person_PhoneNumber >*
964 Person::mutable_phones() {
965     // @@protoc_insertion_point(field_mutable_list:tutorial.Person.phones)
966     return &phones_;
967 }
968 inline const ::tutorial::Person_PhoneNumber& Person::_internal_phones(int index) const {
969     return phones_.Get(index);
970 }
971 inline const ::tutorial::Person_PhoneNumber& Person::phones(int index) const {
972     // @@protoc_insertion_point(field_get:tutorial.Person.phones)
973     return _internal_phones(index);
974 }
975 inline ::tutorial::Person_PhoneNumber* Person::_internal_add_phones() {
976     return phones_.Add();
977 }
978 inline ::tutorial::Person_PhoneNumber* Person::add_phones() {
979     ::tutorial::Person_PhoneNumber* _add = _internal_add_phones();
980     // @@protoc_insertion_point(field_add:tutorial.Person.phones)
981     return _add;
982 }
983 inline const ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person_PhoneNumber >&
984 Person::phones() const {
985     // @@protoc_insertion_point(field_list:tutorial.Person.phones)
986     return phones_;
987 }
988
989 // -----
990
991 // AddressBook
992
993 // repeated .tutorial.Person people = 1;
994 inline int AddressBook::_internal_people_size() const {
995     return people_.size();
996 }
997 inline int AddressBook::people_size() const {

```

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```

998     return _internal_people_size();
999 }
1000 inline void AddressBook::clear_people() {
1001     people_.Clear();
1002 }
1003 inline ::tutorial::Person* AddressBook::mutable_people(int index) {
1004     // @@protoc_insertion_point(field_mutable:tutorial.AddressBook.people)
1005     return people_.Mutable(index);
1006 }
1007 inline ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person >*
1008 AddressBook::mutable_people() {
1009     // @@protoc_insertion_point(field_mutable_list:tutorial.AddressBook.people)
1010     return &people_;
1011 }
1012 inline const ::tutorial::Person& AddressBook::_internal_people(int index) const {
1013     return people_.Get(index);
1014 }
1015 inline const ::tutorial::Person& AddressBook::people(int index) const {
1016     // @@protoc_insertion_point(field_get:tutorial.AddressBook.people)
1017     return _internal_people(index);
1018 }
1019 inline ::tutorial::Person* AddressBook::_internal_add_people() {
1020     return people_.Add();
1021 }
1022 inline ::tutorial::Person* AddressBook::add_people() {
1023     ::tutorial::Person* _add = _internal_add_people();
1024     // @@protoc_insertion_point(field_add:tutorial.AddressBook.people)
1025     return _add;
1026 }
1027 inline const ::PROTOBUF_NAMESPACE_ID::RepeatedPtrField< ::tutorial::Person >&
1028 AddressBook::people() const {
1029     // @@protoc_insertion_point(field_list:tutorial.AddressBook.people)
1030     return people_;
1031 }
1032
1033 #ifdef __GNUC__
1034     #pragma GCC diagnostic pop
1035 #endif // __GNUC__
1036 // -----
1037
1038 // -----
1039
1040 // @@protoc_insertion_point(namespace_scope)
1041
1042 } // namespace tutorial
1043
1044 PROTOBUF_NAMESPACE_OPEN
1045
1046 template <> struct is_proto_enum< ::tutorial::Person_PhoneType> : ::std::true_type {};
1047 template <>
1048 inline const EnumDescriptor* GetEnumDescriptor< ::tutorial::Person_PhoneType>() {
1049

```

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```

1050     return ::tutorial::Person_PhoneType_descriptor();
1051 }
1052
1053 PROTOBUF_NAMESPACE_CLOSE
1054
1055 // @@protoc_insertion_point(global_scope)
1056
1057 #include <google/protobuf/port_undef.inc>
1058 #endif // GOOGLE_PROTOBUF_INCLUDED_GOOGLE_PROTOBUF_INCLUDED_hello_2eproto

```

## 15.2.4 hello.pb.cc

Listing 6: ./code/hello.pb.cc

```

1 // Generated by the protocol buffer compiler.  DO NOT EDIT!
2 // source: hello.proto
3
4 #include "hello.pb.h"
5
6 #include <algorithm>
7
8 #include <google/protobuf/io/coded_stream.h>
9 #include <google/protobuf/extension_set.h>
10 #include <google/protobuf/wire_format_lite.h>
11 #include <google/protobuf/descriptor.h>
12 #include <google/protobuf/generated_message_reflection.h>
13 #include <google/protobuf/reflection_ops.h>
14 #include <google/protobuf/wire_format.h>
15 // @@protoc_insertion_point(includes)
16 #include <google/protobuf/port_def.inc>
17
18 PROTOBUF_PRAGMA_INIT_SEG
19
20 namespace _pb = ::PROTOBUF_NAMESPACE_ID;
21 namespace _pbi = _pb::internal;
22
23 namespace tutorial {
24 PROTOBUF_CONSTEXPR Person_PhoneNumber::Person_PhoneNumber(
25     ::_pbi::ConstantInitialized)
26     : number_(&::_pbi::fixed_address_empty_string, ::_pbi::ConstantInitialized{})
27     , type_(1)
28 {}
29 struct Person_PhoneNumberDefaultTypeInternal {
30     PROTOBUF_CONSTEXPR Person_PhoneNumberDefaultTypeInternal()
31         : _instance(::_pbi::ConstantInitialized{}) {}
32     ~Person_PhoneNumberDefaultTypeInternal() {}
33     union {
34         Person_PhoneNumber _instance;
35     };
36 };

```

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```

37 PROTOBUF_ATTRIBUTE_NO_DESTROY PROTOBUF_CONSTINIT PROTOBUF_ATTRIBUTE_INIT_PRIORITY1
↪ Person_PhoneNumberDefaultTypeInternal _Person_PhoneNumber_default_instance_;
38 PROTOBUF_CONSTEXPR Person::Person(
39     ::_pbi::ConstantInitialized)
40     : phones_()
41     , name_(&::_pbi::fixed_address_empty_string, ::_pbi::ConstantInitialized{})
42     , email_(&::_pbi::fixed_address_empty_string, ::_pbi::ConstantInitialized{})
43     , id_(0){}
44 struct PersonDefaultTypeInternal {
45     PROTOBUF_CONSTEXPR PersonDefaultTypeInternal()
46         : _instance(::_pbi::ConstantInitialized{}) {}
47     ~PersonDefaultTypeInternal() {}
48     union {
49         Person _instance;
50     };
51 };
52 PROTOBUF_ATTRIBUTE_NO_DESTROY PROTOBUF_CONSTINIT PROTOBUF_ATTRIBUTE_INIT_PRIORITY1
↪ PersonDefaultTypeInternal _Person_default_instance_;
53 PROTOBUF_CONSTEXPR AddressBook::AddressBook(
54     ::_pbi::ConstantInitialized)
55     : people_(){}
56 struct AddressBookDefaultTypeInternal {
57     PROTOBUF_CONSTEXPR AddressBookDefaultTypeInternal()
58         : _instance(::_pbi::ConstantInitialized{}) {}
59     ~AddressBookDefaultTypeInternal() {}
60     union {
61         AddressBook _instance;
62     };
63 };
64 PROTOBUF_ATTRIBUTE_NO_DESTROY PROTOBUF_CONSTINIT PROTOBUF_ATTRIBUTE_INIT_PRIORITY1
↪ AddressBookDefaultTypeInternal _AddressBook_default_instance_;
65 } // namespace tutorial
66 static ::_pb::Metadata file_level_metadata_hello_2eproto[3];
67 static const ::_pb::EnumDescriptor* file_level_enum_descriptors_hello_2eproto[1];
68 static constexpr ::_pb::ServiceDescriptor const** file_level_service_descriptors_hello_
↪ 2eproto = nullptr;
69
70 const uint32_t TableStruct_hello_2eproto::offsets[] PROTOBUF_SECTION_VARIABLE(protodesc_
↪ cold) = {
71     PROTOBUF_FIELD_OFFSET(::tutorial::Person_PhoneNumber, _has_bits_),
72     PROTOBUF_FIELD_OFFSET(::tutorial::Person_PhoneNumber, _internal_metadata_),
73     ~0u, // no _extensions_
74     ~0u, // no _oneof_case_
75     ~0u, // no _weak_field_map_
76     ~0u, // no _inlined_string_donated_
77     PROTOBUF_FIELD_OFFSET(::tutorial::Person_PhoneNumber, number_),
78     PROTOBUF_FIELD_OFFSET(::tutorial::Person_PhoneNumber, type_),
79     0,
80     1,
81     PROTOBUF_FIELD_OFFSET(::tutorial::Person, _has_bits_),
82     PROTOBUF_FIELD_OFFSET(::tutorial::Person, _internal_metadata_),
83     ~0u, // no _extensions_

```

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```

84 ~0u, // no _oneof_case_
85 ~0u, // no _weak_field_map_
86 ~0u, // no _inlined_string_donated_
87 PROTOBUF_FIELD_OFFSET(::tutorial::Person, name_),
88 PROTOBUF_FIELD_OFFSET(::tutorial::Person, id_),
89 PROTOBUF_FIELD_OFFSET(::tutorial::Person, email_),
90 PROTOBUF_FIELD_OFFSET(::tutorial::Person, phones_),
91 0,
92 2,
93 1,
94 ~0u,
95 ~0u, // no _has_bits_
96 PROTOBUF_FIELD_OFFSET(::tutorial::AddressBook, _internal_metadata_),
97 ~0u, // no _extensions_
98 ~0u, // no _oneof_case_
99 ~0u, // no _weak_field_map_
100 ~0u, // no _inlined_string_donated_
101 PROTOBUF_FIELD_OFFSET(::tutorial::AddressBook, people_),
102 };
103 static const ::_pbi::MigrationSchema schemas[] PROTOBUF_SECTION_VARIABLE(protodesc_cold) = {
104     ↪= {
105         { 0, 8, -1, sizeof(::tutorial::Person_PhoneNumber)},
106         { 10, 20, -1, sizeof(::tutorial::Person)},
107         { 24, -1, -1, sizeof(::tutorial::AddressBook)},
108     };
109 static const ::_pb::Message* const file_default_instances[] = {
110     &::tutorial::Person_PhoneNumber_default_instance._instance,
111     &::tutorial::Person_default_instance._instance,
112     &::tutorial::AddressBook_default_instance._instance,
113 };
114
115 const char descriptor_table_protodef_hello_2eproto[] PROTOBUF_SECTION_VARIABLE(protodesc_
116 ↪cold) =
117     "\n\013hello.proto\022\010tutorial\"333\001\n\006Person\022\014\n\004na"
118     "me\030\001 \001(\t\022\n\n\002id\030\002 \001(\005\022\r\n\005email\030\003 \001(\t\022\022\n\006p"
119     "hones\030\004 \003(\0132\034.tutorial.Person.PhoneNumbe"
120     "r\032M\n\013PhoneNumber\022\016\n\006number\030\001 \001(\t\022.\n\004type"
121     "\030\002 \001(\0162\032.tutorial.Person.PhoneType:\004HOME"
122     "\"+\n\tPhoneType\022\n\n\006MOBILE\020\000\022\010\n\004HOME\020\001\022\010\n\004W"
123     "ORK\020\002\"/\n\013AddressBook\022 \n\006people\030\001 \003(\0132\020.t"
124     "utorial.Person"
125 ;
126 static ::_pbi::once_flag descriptor_table_hello_2eproto_once;
127 const ::_pbi::DescriptorTable descriptor_table_hello_2eproto = {
128     false, false, 294, descriptor_table_protodef_hello_2eproto,
129     "hello.proto",
130     &descriptor_table_hello_2eproto_once, nullptr, 0, 3,
131     schemas, file_default_instances, TableStruct_hello_2eproto::offsets,
132     file_level_metadata_hello_2eproto, file_level_enum_descriptors_hello_2eproto,
133     file_level_service_descriptors_hello_2eproto,

```

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```

133 };
134 PROTOBUF_ATTRIBUTE_WEAK const ::_pbi::DescriptorTable* descriptor_table_hello_2eproto_
    ↪getter() {
135     return &descriptor_table_hello_2eproto;
136 }
137
138 // Force running AddDescriptors() at dynamic initialization time.
139 PROTOBUF_ATTRIBUTE_INIT_PRIORITY2 static ::_pbi::AddDescriptorsRunner dynamic_init_dummy_
    ↪hello_2eproto(&descriptor_table_hello_2eproto);
140 namespace tutorial {
141 const ::PROTOBUF_NAMESPACE_ID::EnumDescriptor* Person_PhoneType_descriptor() {
142     ::PROTOBUF_NAMESPACE_ID::internal::AssignDescriptors(&descriptor_table_hello_2eproto);
143     return file_level_enum_descriptors_hello_2eproto[0];
144 }
145 bool Person_PhoneType_IsValid(int value) {
146     switch (value) {
147         case 0:
148         case 1:
149         case 2:
150             return true;
151         default:
152             return false;
153     }
154 }
155
156 #if (__cplusplus < 201703) && (!defined(_MSC_VER) || (_MSC_VER >= 1900 && _MSC_VER <
    ↪1912))
157 constexpr Person_PhoneType Person::MOBILE;
158 constexpr Person_PhoneType Person::HOME;
159 constexpr Person_PhoneType Person::WORK;
160 constexpr Person_PhoneType Person::PhoneType_MIN;
161 constexpr Person_PhoneType Person::PhoneType_MAX;
162 constexpr int Person::PhoneType_ARRAYSIZE;
163 #endif // (__cplusplus < 201703) && (!defined(_MSC_VER) || (_MSC_VER >= 1900 && _MSC_
    ↪VER < 1912))
164
165 // =====
166
167 class Person_PhoneNumber::_Internal {
168 public:
169     using HasBits = decltype(std::declval<Person_PhoneNumber>()._has_bits_);
170     static void set_has_number(HasBits* has_bits) {
171         (*has_bits)[0] |= 1u;
172     }
173     static void set_has_type(HasBits* has_bits) {
174         (*has_bits)[0] |= 2u;
175     }
176 };
177
178 Person_PhoneNumber::Person_PhoneNumber(::PROTOBUF_NAMESPACE_ID::Arena* arena,
179     bool is_message_owned)
180     : ::PROTOBUF_NAMESPACE_ID::Message(arena, is_message_owned) {

```

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```

181     SharedCtor();
182     // @@protoc_insertion_point(arena_constructor:tutorial.Person.PhoneNumber)
183 }
184 Person_PhoneNumber::Person_PhoneNumber(const Person_PhoneNumber& from)
185     : ::PROTOBUF_NAMESPACE_ID::Message(),
186       _has_bits_(from._has_bits_) {
187     _internal_metadata_.MergeFrom<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>(from._internal_
188 ↪_metadata_);
189     number_.InitDefault();
190     #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
191         number_.Set("", GetArenaForAllocation());
192     #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
193     if (from._internal_has_number()) {
194         number_.Set(from._internal_number(),
195             GetArenaForAllocation());
196     }
197     type_ = from.type_;
198     // @@protoc_insertion_point(copy_constructor:tutorial.Person.PhoneNumber)
199 }
200 inline void Person_PhoneNumber::SharedCtor() {
201     number_.InitDefault();
202     #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
203         number_.Set("", GetArenaForAllocation());
204     #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
205     type_ = 1;
206 }
207
208 Person_PhoneNumber::~Person_PhoneNumber() {
209     // @@protoc_insertion_point(destructor:tutorial.Person.PhoneNumber)
210     if (auto *arena = _internal_metadata_.DeleteReturnArena<::PROTOBUF_NAMESPACE_
211 ↪ID::UnknownFieldSet>()) {
212         (void)arena;
213         return;
214     }
215     SharedDtor();
216 }
217 inline void Person_PhoneNumber::SharedDtor() {
218     GOOGLE_DCHECK(GetArenaForAllocation() == nullptr);
219     number_.Destroy();
220 }
221
222 void Person_PhoneNumber::SetCachedSize(int size) const {
223     _cached_size_.Set(size);
224 }
225
226 void Person_PhoneNumber::Clear() {
227     // @@protoc_insertion_point(message_clear_start:tutorial.Person.PhoneNumber)
228     uint32_t cached_has_bits = 0;
229     // Prevent compiler warnings about cached_has_bits being unused
230     (void) cached_has_bits;

```

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```

231
232 cached_has_bits = _has_bits_[0];
233 if (cached_has_bits & 0x000000003u) {
234     if (cached_has_bits & 0x000000001u) {
235         number_.ClearNonDefaultToEmpty();
236     }
237     type_ = 1;
238 }
239 _has_bits_.Clear();
240 _internal_metadata_.Clear<:PROTOBUF_NAMESPACE_ID::UnknownFieldSet>();
241 }
242
243 const char* Person_PhoneNumber::_InternalParse(const char* ptr, ::_pbi::ParseContext*
↪ ctx) {
244 #define CHK_(x) if (PROTOBUF_PREDICT_FALSE(!(x))) goto failure
245 _Internal::HasBits has_bits{};
246 while (!ctx->Done(&ptr)) {
247     uint32_t tag;
248     ptr = ::_pbi::ReadTag(ptr, &tag);
249     switch (tag >> 3) {
250         // optional string number = 1;
251         case 1:
252             if (PROTOBUF_PREDICT_TRUE(static_cast<uint8_t>(tag) == 10)) {
253                 auto str = _internal_mutable_number();
254                 ptr = ::_pbi::InlineGreedyStringParser(str, ptr, ctx);
255                 CHK_(ptr);
256                 #ifndef NDEBUG
257                 ::_pbi::VerifyUTF8(str, "tutorial.Person.PhoneNumber.number");
258                 #endif // !NDEBUG
259             } else
260                 goto handle_unusual;
261             continue;
262         // optional .tutorial.Person.PhoneType type = 2 [default = HOME];
263         case 2:
264             if (PROTOBUF_PREDICT_TRUE(static_cast<uint8_t>(tag) == 16)) {
265                 uint64_t val = ::PROTOBUF_NAMESPACE_ID::internal::ReadVarint64(&ptr);
266                 CHK_(ptr);
267                 if (PROTOBUF_PREDICT_TRUE(::tutorial::Person_PhoneType_IsValid(val))) {
268                     _internal_set_type(static_cast<:tutorial::Person_PhoneType>(val));
269                 } else {
270                     ::PROTOBUF_NAMESPACE_ID::internal::WriteVarint(2, val, mutable_unknown_
↪ fields());
271                 }
272             } else
273                 goto handle_unusual;
274             continue;
275         default:
276             goto handle_unusual;
277     } // switch
278 handle_unusual:
279     if ((tag == 0) || ((tag & 7) == 4)) {
280         CHK_(ptr);

```

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```

281     ctx->SetLastTag(tag);
282     goto message_done;
283 }
284 ptr = UnknownFieldParse(
285     tag,
286     _internal_metadata_.mutable_unknown_fields<:PROTOBUF_NAMESPACE_
↪ID::UnknownFieldSet>(),
287     ptr, ctx);
288     CHK_(ptr != nullptr);
289 } // while
290 message_done:
291     _has_bits_.Or(has_bits);
292     return ptr;
293 failure:
294     ptr = nullptr;
295     goto message_done;
296 #undef CHK_
297 }
298
299 uint8_t* Person_PhoneNumber::_InternalSerialize(
300     uint8_t* target, ::PROTOBUF_NAMESPACE_ID::io::EpsCopyOutputStream* stream) const {
301     // @@protoc_insertion_point(serialize_to_array_start:tutorial.Person.PhoneNumber)
302     uint32_t cached_has_bits = 0;
303     (void) cached_has_bits;
304
305     cached_has_bits = _has_bits_[0];
306     // optional string number = 1;
307     if (cached_has_bits & 0x00000001u) {
308         ::PROTOBUF_NAMESPACE_ID::internal::WireFormat::VerifyUTF8StringNamedField(
309             this->_internal_number().data(), static_cast<int>(this->_internal_number().
↪length()),
310             ::PROTOBUF_NAMESPACE_ID::internal::WireFormat::SERIALIZE,
311             "tutorial.Person.PhoneNumber.number");
312         target = stream->WriteStringMaybeAliased(
313             1, this->_internal_number(), target);
314     }
315
316     // optional .tutorial.Person.PhoneType type = 2 [default = HOME];
317     if (cached_has_bits & 0x00000002u) {
318         target = stream->EnsureSpace(target);
319         target = ::_pbi::WireFormatLite::WriteEnumToArray(
320             2, this->_internal_type(), target);
321     }
322
323     if (PROTOBUF_PREDICT_FALSE(_internal_metadata_.have_unknown_fields())) {
324         target = ::_pbi::WireFormat::InternalSerializeUnknownFieldsToArray(
325             _internal_metadata_.unknown_fields<:PROTOBUF_NAMESPACE_ID::UnknownFieldSet>
↪(::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance), target, stream);
326     }
327     // @@protoc_insertion_point(serialize_to_array_end:tutorial.Person.PhoneNumber)
328     return target;
329 }

```

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```

330
331 size_t Person_PhoneNumber::ByteSizeLong() const {
332 // @@protoc_insertion_point(message_byte_size_start:tutorial.Person.PhoneNumber)
333     size_t total_size = 0;
334
335     uint32_t cached_has_bits = 0;
336     // Prevent compiler warnings about cached_has_bits being unused
337     (void) cached_has_bits;
338
339     cached_has_bits = _has_bits_[0];
340     if (cached_has_bits & 0x00000003u) {
341         // optional string number = 1;
342         if (cached_has_bits & 0x00000001u) {
343             total_size += 1 +
344                 ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::StringSize(
345                 this->_internal_number());
346         }
347
348         // optional .tutorial.Person.PhoneType type = 2 [default = HOME];
349         if (cached_has_bits & 0x00000002u) {
350             total_size += 1 +
351                 ::_pbi::WireFormatLite::EnumSize(this->_internal_type());
352         }
353     }
354
355     return MaybeComputeUnknownFieldsSize(total_size, &_cached_size_);
356 }
357
358 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData Person_PhoneNumber::_class_data_ = {
359     ::PROTOBUF_NAMESPACE_ID::Message::CopyWithSizeCheck,
360     Person_PhoneNumber::MergeImpl
361 };
362 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData*Person_PhoneNumber::GetClassData() {
363     ↪ const { return &_class_data_; }
364
365 void Person_PhoneNumber::MergeImpl(::PROTOBUF_NAMESPACE_ID::Message* to,
366     const ::PROTOBUF_NAMESPACE_ID::Message& from) {
367     static_cast<Person_PhoneNumber *>(to)->MergeFrom(
368         static_cast<const Person_PhoneNumber &>(from));
369 }
370
371 void Person_PhoneNumber::MergeFrom(const Person_PhoneNumber& from) {
372 // @@protoc_insertion_point(class_specific_merge_from_start:tutorial.Person.PhoneNumber)
373     GOOGLE_DCHECK_NE(&from, this);
374     uint32_t cached_has_bits = 0;
375     (void) cached_has_bits;
376
377     cached_has_bits = from._has_bits_[0];
378     if (cached_has_bits & 0x00000003u) {
379         if (cached_has_bits & 0x00000001u) {
380             _internal_set_number(from._internal_number());

```

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```

381     }
382     if (cached_has_bits & 0x00000002u) {
383         type_ = from.type_;
384     }
385     _has_bits_[0] |= cached_has_bits;
386 }
387 _internal_metadata_.MergeFrom<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>(from._internal_
↪ metadata_);
388 }
389
390 void Person_PhoneNumber::CopyFrom(const Person_PhoneNumber& from) {
391     // @@protoc_insertion_point(class_specific_copy_from_start:tutorial.Person.PhoneNumber)
392     if (&from == this) return;
393     Clear();
394     MergeFrom(from);
395 }
396
397 bool Person_PhoneNumber::IsInitialized() const {
398     return true;
399 }
400
401 void Person_PhoneNumber::InternalSwap(Person_PhoneNumber* other) {
402     using std::swap;
403     auto* lhs_arena = GetArenaForAllocation();
404     auto* rhs_arena = other->GetArenaForAllocation();
405     _internal_metadata_.InternalSwap(&other->_internal_metadata_);
406     swap(_has_bits_[0], other->_has_bits_[0]);
407     ::PROTOBUF_NAMESPACE_ID::internal::ArenaStringPtr::InternalSwap(
408         &number_, lhs_arena,
409         &other->number_, rhs_arena
410     );
411     swap(type_, other->type_);
412 }
413
414 ::PROTOBUF_NAMESPACE_ID::Metadata Person_PhoneNumber::GetMetadata() const {
415     return ::_pbi::AssignDescriptors(
416         &descriptor_table_hello_2eproto_getter, &descriptor_table_hello_2eproto_once,
417         file_level_metadata_hello_2eproto[0]);
418 }
419
420 // =====
421
422 class Person::_Internal {
423 public:
424     using HasBits = decltype(std::declval<Person>()._has_bits_);
425     static void set_has_name(HasBits* has_bits) {
426         (*has_bits)[0] |= 1u;
427     }
428     static void set_has_id(HasBits* has_bits) {
429         (*has_bits)[0] |= 4u;
430     }
431     static void set_has_email(HasBits* has_bits) {

```

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```

432     (*has_bits)[0] |= 2u;
433 }
434 };
435
436 Person::Person(::PROTOBUF_NAMESPACE_ID::Arena* arena,
437               bool is_message_owned)
438   : ::PROTOBUF_NAMESPACE_ID::Message(arena, is_message_owned),
439   phones_(arena) {
440   SharedCtor();
441   // @@protoc_insertion_point(arena_constructor:tutorial.Person)
442 }
443 Person::Person(const Person& from)
444   : ::PROTOBUF_NAMESPACE_ID::Message(),
445   _has_bits_(from._has_bits_),
446   phones_(from.phones_) {
447   _internal_metadata_.MergeFrom<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>(from._internal_
↳ metadata_);
448   name_.InitDefault();
449   #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
450     name_.Set("", GetArenaForAllocation());
451   #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
452   if (from._internal_has_name()) {
453     name_.Set(from._internal_name(),
454              GetArenaForAllocation());
455   }
456   email_.InitDefault();
457   #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
458     email_.Set("", GetArenaForAllocation());
459   #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
460   if (from._internal_has_email()) {
461     email_.Set(from._internal_email(),
462               GetArenaForAllocation());
463   }
464   id_ = from.id_;
465   // @@protoc_insertion_point(copy_constructor:tutorial.Person)
466 }
467
468 inline void Person::SharedCtor() {
469   name_.InitDefault();
470   #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
471     name_.Set("", GetArenaForAllocation());
472   #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
473   email_.InitDefault();
474   #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
475     email_.Set("", GetArenaForAllocation());
476   #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
477   id_ = 0;
478 }
479
480 Person::~Person() {
481   // @@protoc_insertion_point(destructor:tutorial.Person)
482   if (auto *arena = _internal_metadata_.DeleteReturnArena<::PROTOBUF_NAMESPACE_
↳ ID::UnknownFieldSet>()) {

```

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```

483 (void)arena;
484     return;
485 }
486 SharedDtor();
487 }
488
489 inline void Person::SharedDtor() {
490     GOOGLE_DCHECK(GetArenaForAllocation() == nullptr);
491     name_.Destroy();
492     email_.Destroy();
493 }
494
495 void Person::SetCachedSize(int size) const {
496     _cached_size_.Set(size);
497 }
498
499 void Person::Clear() {
500     // @@protoc_insertion_point(message_clear_start:tutorial.Person)
501     uint32_t cached_has_bits = 0;
502     // Prevent compiler warnings about cached_has_bits being unused
503     (void) cached_has_bits;
504
505     phones_.Clear();
506     cached_has_bits = _has_bits_[0];
507     if (cached_has_bits & 0x000000003u) {
508         if (cached_has_bits & 0x000000001u) {
509             name_.ClearNonDefaultToEmpty();
510         }
511         if (cached_has_bits & 0x000000002u) {
512             email_.ClearNonDefaultToEmpty();
513         }
514     }
515     id_ = 0;
516     _has_bits_.Clear();
517     _internal_metadata_.Clear<:PROTOBUF_NAMESPACE_ID::UnknownFieldSet>();
518 }
519
520 const char* Person::_InternalParse(const char* ptr, ::_pbi::ParseContext* ctx) {
521     #define CHK_(x) if (PROTOBUF_PREDICT_FALSE(!(x))) goto failure
522     _Internal::HasBits has_bits{};
523     while (!ctx->Done(&ptr)) {
524         uint32_t tag;
525         ptr = ::_pbi::ReadTag(ptr, &tag);
526         switch (tag >> 3) {
527             // optional string name = 1;
528             case 1:
529                 if (PROTOBUF_PREDICT_TRUE(static_cast<uint8_t>(tag) == 10)) {
530                     auto str = _internal_mutable_name();
531                     ptr = ::_pbi::InlineGreedyStringParser(str, ptr, ctx);
532                     CHK_(ptr);
533                     #ifndef NDEBUG
534                     ::_pbi::VerifyUTF8(str, "tutorial.Person.name");
535                     #endif
536                 }
537             default:
538                 goto failure;
539         }
540     }
541     #undef CHK_
542     return ptr;
543 }

```

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```

535     #endif // !NDEBUG
536   } else
537     goto handle_unusual;
538   continue;
539   // optional int32 id = 2;
540   case 2:
541     if (PROTOBUF_PREDICT_TRUE(static_cast<uint8_t>(tag) == 16)) {
542       _Internal::set_has_id(&has_bits);
543       id = ::PROTOBUF_NAMESPACE_ID::internal::ReadVarint32(&ptr);
544       CHK_(ptr);
545     } else
546       goto handle_unusual;
547     continue;
548   // optional string email = 3;
549   case 3:
550     if (PROTOBUF_PREDICT_TRUE(static_cast<uint8_t>(tag) == 26)) {
551       auto str = _internal_mutable_email();
552       ptr = ::_pbi::InlineGreedyStringParser(str, ptr, ctx);
553       CHK_(ptr);
554       #ifndef NDEBUG
555       ::_pbi::VerifyUTF8(str, "tutorial.Person.email");
556       #endif // !NDEBUG
557     } else
558       goto handle_unusual;
559     continue;
560   // repeated .tutorial.Person.PhoneNumber phones = 4;
561   case 4:
562     if (PROTOBUF_PREDICT_TRUE(static_cast<uint8_t>(tag) == 34)) {
563       ptr -= 1;
564       do {
565         ptr += 1;
566         ptr = ctx->ParseMessage(_internal_add_phones(), ptr);
567         CHK_(ptr);
568         if (!ctx->DataAvailable(ptr)) break;
569       } while (::PROTOBUF_NAMESPACE_ID::internal::ExpectTag<34>(ptr));
570     } else
571       goto handle_unusual;
572     continue;
573   default:
574     goto handle_unusual;
575   } // switch
576   handle_unusual:
577   if ((tag == 0) || ((tag & 7) == 4)) {
578     CHK_(ptr);
579     ctx->SetLastTag(tag);
580     goto message_done;
581   }
582   ptr = UnknownFieldParse(
583     tag,
584     _internal_metadata_.mutable_unknown_fields<::PROTOBUF_NAMESPACE_
585     ID::UnknownFieldSet>(),
    ptr, ctx);

```

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```

586     CHK_(ptr != nullptr);
587 } // while
588 message_done:
589     _has_bits_.Or(has_bits);
590     return ptr;
591 failure:
592     ptr = nullptr;
593     goto message_done;
594 #undef CHK_
595 }
596
597 uint8_t* Person::_InternalSerialize(
598     uint8_t* target, ::PROTOBUF_NAMESPACE_ID::io::EpsCopyOutputStream* stream) const {
599     // @@protoc_insertion_point(serialize_to_array_start:tutorial.Person)
600     uint32_t cached_has_bits = 0;
601     (void) cached_has_bits;
602
603     cached_has_bits = _has_bits_[0];
604     // optional string name = 1;
605     if (cached_has_bits & 0x000000001u) {
606         ::PROTOBUF_NAMESPACE_ID::internal::WireFormat::VerifyUTF8StringNamedField(
607             this->_internal_name().data(), static_cast<int>(this->_internal_name().length()),
608             ::PROTOBUF_NAMESPACE_ID::internal::WireFormat::SERIALIZE,
609             "tutorial.Person.name");
610         target = stream->WriteStringMaybeAliased(
611             1, this->_internal_name(), target);
612     }
613
614     // optional int32 id = 2;
615     if (cached_has_bits & 0x000000004u) {
616         target = stream->EnsureSpace(target);
617         target = ::_pbi::WireFormatLite::WriteInt32ToArray(2, this->_internal_id(), target);
618     }
619
620     // optional string email = 3;
621     if (cached_has_bits & 0x000000002u) {
622         ::PROTOBUF_NAMESPACE_ID::internal::WireFormat::VerifyUTF8StringNamedField(
623             this->_internal_email().data(), static_cast<int>(this->_internal_email().length()),
624             ::PROTOBUF_NAMESPACE_ID::internal::WireFormat::SERIALIZE,
625             "tutorial.Person.email");
626         target = stream->WriteStringMaybeAliased(
627             3, this->_internal_email(), target);
628     }
629
630     // repeated .tutorial.Person.PhoneNumber phones = 4;
631     for (unsigned i = 0,
632         n = static_cast<unsigned>(this->_internal_phones_size()); i < n; i++) {
633         const auto& repfield = this->_internal_phones(i);
634         target = ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::
635             InternalWriteMessage(4, repfield, repfield.GetCachedSize(), target, stream);
636     }
637

```

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```

638     if (PROTOBUF_PREDICT_FALSE(_internal_metadata_.have_unknown_fields())) {
639         target = ::_pbi::WireFormat::InternalSerializeUnknownFieldsToArray(
640             _internal_metadata_.unknown_fields<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>
641             ↪ (::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance), target, stream);
642     }
643     // @@protoc_insertion_point(serialize_to_array_end:tutorial.Person)
644     return target;
645 }
646
647 size_t Person::ByteSizeLong() const {
648     // @@protoc_insertion_point(message_byte_size_start:tutorial.Person)
649     size_t total_size = 0;
650
651     uint32_t cached_has_bits = 0;
652     // Prevent compiler warnings about cached_has_bits being unused
653     (void) cached_has_bits;
654
655     // repeated .tutorial.Person.PhoneNumber phones = 4;
656     total_size += 1UL * this->_internal_phones_size();
657     for (const auto& msg : this->phones_) {
658         total_size +=
659             ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::MessageSize(msg);
660     }
661
662     cached_has_bits = _has_bits_[0];
663     if (cached_has_bits & 0x000000007u) {
664         // optional string name = 1;
665         if (cached_has_bits & 0x000000001u) {
666             total_size += 1 +
667                 ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::StringSize(
668                     this->_internal_name());
669         }
670
671         // optional string email = 3;
672         if (cached_has_bits & 0x000000002u) {
673             total_size += 1 +
674                 ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::StringSize(
675                     this->_internal_email());
676         }
677
678         // optional int32 id = 2;
679         if (cached_has_bits & 0x000000004u) {
680             total_size += ::_pbi::WireFormatLite::Int32SizePlusOne(this->_internal_id());
681         }
682     }
683     return MaybeComputeUnknownFieldsSize(total_size, &_cached_size_);
684 }
685
686 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData Person::_class_data_ = {
687     ::PROTOBUF_NAMESPACE_ID::Message::CopyWithSizeCheck,
688     Person::MergeImpl

```

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```

689 };
690 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData*Person::GetClassData() const { return &
↳_class_data_; }
691
692 void Person::MergeImpl(::PROTOBUF_NAMESPACE_ID::Message* to,
693                       const ::PROTOBUF_NAMESPACE_ID::Message& from) {
694     static_cast<Person*>(to)->MergeFrom(
695         static_cast<const Person&>(from));
696 }
697
698
699 void Person::MergeFrom(const Person& from) {
700     // @@protoc_insertion_point(class_specific_merge_from_start:tutorial.Person)
701     GOOGLE_DCHECK_NE(&from, this);
702     uint32_t cached_has_bits = 0;
703     (void) cached_has_bits;
704
705     phones_.MergeFrom(from.phones_);
706     cached_has_bits = from._has_bits_[0];
707     if (cached_has_bits & 0x00000007u) {
708         if (cached_has_bits & 0x00000001u) {
709             _internal_set_name(from._internal_name());
710         }
711         if (cached_has_bits & 0x00000002u) {
712             _internal_set_email(from._internal_email());
713         }
714         if (cached_has_bits & 0x00000004u) {
715             id_ = from.id_;
716         }
717         _has_bits_[0] |= cached_has_bits;
718     }
719     _internal_metadata_.MergeFrom<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>(from._internal_
↳metadata_);
720 }
721
722 void Person::CopyFrom(const Person& from) {
723     // @@protoc_insertion_point(class_specific_copy_from_start:tutorial.Person)
724     if (&from == this) return;
725     Clear();
726     MergeFrom(from);
727 }
728
729 bool Person::IsInitialized() const {
730     return true;
731 }
732
733 void Person::InternalSwap(Person* other) {
734     using std::swap;
735     auto* lhs_arena = GetArenaForAllocation();
736     auto* rhs_arena = other->GetArenaForAllocation();
737     _internal_metadata_.InternalSwap(&other->_internal_metadata_);
738     swap(_has_bits_[0], other->_has_bits_[0]);

```

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```

739 phones_.InternalSwap(&other->phones_);
740 ::PROTOBUF_NAMESPACE_ID::internal::ArenaStringPtr::InternalSwap(
741     &name_, lhs_arena,
742     &other->name_, rhs_arena
743 );
744 ::PROTOBUF_NAMESPACE_ID::internal::ArenaStringPtr::InternalSwap(
745     &email_, lhs_arena,
746     &other->email_, rhs_arena
747 );
748 swap(id_, other->id_);
749 }
750
751 ::PROTOBUF_NAMESPACE_ID::Metadata Person::GetMetadata() const {
752     return ::_pbi::AssignDescriptors(
753         &descriptor_table_hello_2eproto_getter, &descriptor_table_hello_2eproto_once,
754         file_level_metadata_hello_2eproto[1]);
755 }
756
757 // =====
758
759 class AddressBook::_Internal {
760 public:
761 };
762
763 AddressBook::AddressBook(::PROTOBUF_NAMESPACE_ID::Arena* arena,
764                          bool is_message_owned)
765     : ::PROTOBUF_NAMESPACE_ID::Message(arena, is_message_owned),
766     people_(arena) {
767     SharedCtor();
768     // @@protoc_insertion_point(arena_constructor:tutorial.AddressBook)
769 }
770 AddressBook::AddressBook(const AddressBook& from)
771     : ::PROTOBUF_NAMESPACE_ID::Message(),
772     people_(from.people_) {
773     _internal_metadata_.MergeFrom<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>(from._internal_
774 ↪ metadata_);
775     // @@protoc_insertion_point(copy_constructor:tutorial.AddressBook)
776 }
777
778 inline void AddressBook::SharedCtor() {
779 }
780
781 AddressBook::~AddressBook() {
782     // @@protoc_insertion_point(destructor:tutorial.AddressBook)
783     if (auto *arena = _internal_metadata_.DeleteReturnArena<::PROTOBUF_NAMESPACE_
784 ↪ ID::UnknownFieldSet>()) {
785         (void)arena;
786         return;
787     }
788     SharedDtor();
789 }

```

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```

789 inline void AddressBook::SharedDtor() {
790     GOOGLE_DCHECK(GetArenaForAllocation() == nullptr);
791 }
792
793 void AddressBook::SetCachedSize(int size) const {
794     _cached_size_.Set(size);
795 }
796
797 void AddressBook::Clear() {
798     // @@protoc_insertion_point(message_clear_start:tutorial.AddressBook)
799     uint32_t cached_has_bits = 0;
800     // Prevent compiler warnings about cached_has_bits being unused
801     (void) cached_has_bits;
802
803     people_.Clear();
804     _internal_metadata_.Clear<:PROTOBUF_NAMESPACE_ID::UnknownFieldSet>();
805 }
806
807 const char* AddressBook::_InternalParse(const char* ptr, ::_pbi::ParseContext* ctx) {
808     #define CHK_(x) if (PROTOBUF_PREDICT_FALSE(!(x))) goto failure
809     while (!ctx->Done(&ptr)) {
810         uint32_t tag;
811         ptr = ::_pbi::ReadTag(ptr, &tag);
812         switch (tag >> 3) {
813             // repeated .tutorial.Person people = 1;
814             case 1:
815                 if (PROTOBUF_PREDICT_TRUE(static_cast<uint8_t>(tag) == 10)) {
816                     ptr -= 1;
817                     do {
818                         ptr += 1;
819                         ptr = ctx->ParseMessage(_internal_add_people(), ptr);
820                         CHK_(ptr);
821                         if (!ctx->DataAvailable(ptr)) break;
822                     } while (::PROTOBUF_NAMESPACE_ID::internal::ExpectTag<10>(ptr));
823                 } else
824                     goto handle_unusual;
825                 continue;
826             default:
827                 goto handle_unusual;
828         } // switch
829     handle_unusual:
830         if ((tag == 0) || ((tag & 7) == 4)) {
831             CHK_(ptr);
832             ctx->SetLastTag(tag);
833             goto message_done;
834         }
835         ptr = UnknownFieldParse(
836             tag,
837             _internal_metadata_.mutable_unknown_fields<:PROTOBUF_NAMESPACE_
838             ID::UnknownFieldSet>(),
839             ptr, ctx);
840         CHK_(ptr != nullptr);

```

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```

840     } // while
841 message_done:
842     return ptr;
843 failure:
844     ptr = nullptr;
845     goto message_done;
846 #undef CHK_
847 }
848
849 uint8_t* AddressBook::_InternalSerialize(
850     uint8_t* target, ::PROTOBUF_NAMESPACE_ID::io::EpsCopyOutputStream* stream) const {
851     // @@protoc_insertion_point(serialize_to_array_start:tutorial.AddressBook)
852     uint32_t cached_has_bits = 0;
853     (void) cached_has_bits;
854
855     // repeated .tutorial.Person people = 1;
856     for (unsigned i = 0,
857          n = static_cast<unsigned>(this->_internal_people_size()); i < n; i++) {
858         const auto& repfield = this->_internal_people(i);
859         target = ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::
860             InternalWriteMessage(1, repfield, repfield.GetCachedSize(), target, stream);
861     }
862
863     if (PROTOBUF_PREDICT_FALSE(_internal_metadata_.have_unknown_fields())) {
864         target = ::_pbi::WireFormat::InternalSerializeUnknownFieldsToArray(
865             _internal_metadata_.unknown_fields<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>
866             ↪ (::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance), target, stream);
867     }
868     // @@protoc_insertion_point(serialize_to_array_end:tutorial.AddressBook)
869     return target;
870 }
871
872 size_t AddressBook::ByteSizeLong() const {
873     // @@protoc_insertion_point(message_byte_size_start:tutorial.AddressBook)
874     size_t total_size = 0;
875
876     uint32_t cached_has_bits = 0;
877     // Prevent compiler warnings about cached_has_bits being unused
878     (void) cached_has_bits;
879
880     // repeated .tutorial.Person people = 1;
881     total_size += 1UL * this->_internal_people_size();
882     for (const auto& msg : this->people_) {
883         total_size +=
884             ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::MessageSize(msg);
885     }
886
887     return MaybeComputeUnknownFieldsSize(total_size, &_cached_size_);
888 }
889
890 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData AddressBook::_class_data_ = {
891     ::PROTOBUF_NAMESPACE_ID::Message::CopyWithSizeCheck,

```

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```

891     AddressBook::MergeImpl
892 };
893 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData*AddressBook::GetClassData() const {
894     ↪return &_class_data_; }
895
896 void AddressBook::MergeImpl(::PROTOBUF_NAMESPACE_ID::Message* to,
897                             const ::PROTOBUF_NAMESPACE_ID::Message& from) {
898     static_cast<AddressBook*>(to)->MergeFrom(
899         static_cast<const AddressBook&>(from));
900 }
901
902 void AddressBook::MergeFrom(const AddressBook& from) {
903     // @@protoc_insertion_point(class_specific_merge_from_start:tutorial.AddressBook)
904     GOOGLE_DCHECK_NE(&from, this);
905     uint32_t cached_has_bits = 0;
906     (void) cached_has_bits;
907
908     people_.MergeFrom(from.people_);
909     _internal_metadata_.MergeFrom<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>(from._internal_
910     ↪metadata_);
911 }
912
913 void AddressBook::CopyFrom(const AddressBook& from) {
914     // @@protoc_insertion_point(class_specific_copy_from_start:tutorial.AddressBook)
915     if (&from == this) return;
916     Clear();
917     MergeFrom(from);
918 }
919
920 bool AddressBook::IsInitialized() const {
921     return true;
922 }
923
924 void AddressBook::InternalSwap(AddressBook* other) {
925     using std::swap;
926     _internal_metadata_.InternalSwap(&other->_internal_metadata_);
927     people_.InternalSwap(&other->people_);
928 }
929
930 ::PROTOBUF_NAMESPACE_ID::Metadata AddressBook::GetMetadata() const {
931     return ::_pbi::AssignDescriptors(
932         &descriptor_table_hello_2eproto_getter, &descriptor_table_hello_2eproto_once,
933         file_level_metadata_hello_2eproto[2]);
934 }
935
936 // @@protoc_insertion_point(namespace_scope)
937 } // namespace tutorial
938 PROTOBUF_NAMESPACE_OPEN
939 template<> PROTOBUF_NOINLINE ::tutorial::Person_PhoneNumber*
940 Arena::CreateMaybeMessage< ::tutorial::Person_PhoneNumber >(Arena* arena) {
941     return Arena::CreateMessageInternal< ::tutorial::Person_PhoneNumber >(arena);

```

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```
941 }
942 template<> PROTOBUF_NOINLINE ::tutorial::Person*
943 Arena::CreateMaybeMessage< ::tutorial::Person >(Arena* arena) {
944     return Arena::CreateMessageInternal< ::tutorial::Person >(arena);
945 }
946 template<> PROTOBUF_NOINLINE ::tutorial::AddressBook*
947 Arena::CreateMaybeMessage< ::tutorial::AddressBook >(Arena* arena) {
948     return Arena::CreateMessageInternal< ::tutorial::AddressBook >(arena);
949 }
950 PROTOBUF_NAMESPACE_CLOSE
951
952 // @@protoc_insertion_point(global_scope)
953 #include <google/protobuf/port_undef.inc>
```





## 16.1 Install

See <https://grpc.io/docs/languages/cpp/quickstart/>

```
git clone --recurse-submodules -b v1.46.3 --depth 1 --shallow-submodules https://github.
↳com/grpc/grpc
mkdir build
cd build
cmake -Dgrpc_INSTALL=ON -Dgrpc_BUILD_TESTS=OFF -DCMAKE_INSTALL_PREFIX=/ceph-fj/fangjun/
↳software/grpc-1.46.3 .. 2>&1 | tee cmake-configure-1.log
make -j20 2>&1 | tee make-1.log
make install 2>&1 | tee make-2.log
```



## 17.1 TODOs

- Striking gold in binutils  
<https://lwn.net/Articles/274859/>
- A ToC of the 20 part linker essay  
<https://lwn.net/Articles/276782/>

There are other resources for linkers and loaders, see

- Executables linking and loading reading  
<http://research.tedneward.com/reading/software/linking-loading/index.html>
- Optimizing real-world applications with GCC Link Time Optimization  
<https://pdfs.semanticscholar.org/6adf/872e3533f40a607f39cdeaf264585efde9af.pdf>  
by Honza Hubicka, whose scholar page is <https://scholar.google.cz/citations?user=vhXJ0JEAAAAJ&hl=en>



## LINKER AND LOADER

### 18.1 References

- A ToC of the 20 part linker essay  
<https://lwn.net/Articles/276782/>, which is written by Ian Lance Taylor
  1. Introduction, personal history, first half of what's-a-linker
  2. What's-a-linker: Dynamic linking, linker data types, linker operation
  3. Address spaces, Object file formats
  4. Shared Libraries
  5. More Shared Libraries -- specifically, linker implementation; ELF Symbols
- <https://www.ucw.cz/~hubicka/>, author of the gold linker
- Rod Evans: Surfing With a Linker Alien <http://www.linker-aliens.org/blogs/rie/>
  1. Hello there
- Michael Walker's Weblog <http://www.linker-aliens.org/blogs/msw/>
  1. Hello World
  2. How to build a Shared Library
  3. Library Bindings - let's be a little bit more precise shall we

---

**Note:** It shows the usage of LD\_DEBUG, pldd, ldd, pgrep elfdump.

---

- Solaris Linking Blogs (Combined Index) <http://www.linker-aliens.org/blogs/>
- LD\_LIBRARY\_PATH - just say no  
[http://www.linker-aliens.org/blogs/rie/entry/tt\\_ld\\_library\\_path\\_tt/](http://www.linker-aliens.org/blogs/rie/entry/tt_ld_library_path_tt/)
- <https://github.com/berkus/odin/blob/master/tools/sjofn/sjofn.c>  
An ELF linker. Read its source code!

## 18.2 Questions

1. How to view PLT?
2. How to view the relocation information? How many types of relocation are there?
3. What PIC code and non-PIC code look like?
4. What is lazy binding and how to use `LD_BIND_NOW`?
5. What is PLT and GOT?

## 19.1 aishell

### 19.1.1 AM training

The first one was added on 2019-02-01.

`asr_train.py` is in `espnet/bin/asr_train.py`, which invokes `espnet.asr.pytorch_backend.asr.train`.

The model is from `espnet.nets.pytorch_backend.e2e_asr.E2E`.

The encoder type *vggblstm*, 3 layers, hidden dim, 1024, proj dim 1024, subsampling 1\_2\_2\_1\_1.

Command is:

```
asr_train.py \
  --config conf/train.yaml \
  --preprocess-conf \
  --ngpu 1 \
  --backend pytorch \
  --outdir exp/xxx \
  --debugmode 1 \
  --dict data/lang_char/train_sp_units.txt
  --minibatches 0 \
  --verbose 0 \
  --resume \
  --train-json xxx/data.json \
  --valid-json yyy/data.json
```





## 20.1 Tutorials

- <https://cmake.org/cmake/help/latest/guide/tutorial/index.html>

## 20.2 Install

Go to <https://github.com/Kitware/CMake/releases> for download.

```
wget https://github.com/Kitware/CMake/releases/download/v3.10.3/cmake-3.10.3-Linux-x86_
↪64.sh
chmod +x ./cmake-3.10.3-Linux-x86_64.sh
./cmake-3.10.3-Linux-x86_64.sh --help
mkdir /path/to/software/cmake-3.10.3
./cmake-3.10.3-Linux-x86_64.sh --prefix=/path/to/software/cmake-3.10.3 --skip-license
export PATH=/path/to/software/cmake-3.10.3/bin:$PATH
```



## HUGGINGFACE

### 21.1 spaces

#### 21.1.1 Install client API

```
pip install huggingface_hub
```

```
(py38) kuangfangjun:t$ python3
Python 3.8.0 (default, Oct 28 2019, 16:14:01)
[GCC 8.3.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> from huggingface_hub import hf_hub_download
>>> hf_hub_download(repo_id="google/pegasus-xsum", filename="config.json")
Downloading: 100%|-----| 1.39k/1.39k [00:00<00:00, 1.12MB/s]
'/root/fangjun/.cache/huggingface/hub/models--google--pegasus-xsum/snapshots/
a0aa5531c00f59a32a167b75130805098b046f9c/config.json'
>>>
```

#### 21.1.2 gradio

- <https://huggingface.co/spaces/alphacep/asr>
- <https://huggingface.co/spaces/jonatasgrosman/asr>
- <https://github.com/gradio-app/gradio/issues/1359>
- <https://huggingface.co/spaces/Gradio-Blocks/neon-tts-plugin-coqui/blob/main/app.py>, css styles



## EECS E6870 SPEECH RECOGNITION

### 22.1 Notes

- <https://www.ee.columbia.edu/~stanchen/spring16/e6870/outline.html>
  - username: speech
  - password: pythonrules



## 23.1 Hello

```
git clone https://github.com/tencent/ncnn
cd ncnn
git checkout 7b4e77671a4457a414b60cee5425758212e725cf
mkdir build
cd build
cmake -DCMAKE_PREFIX_PATH=/ceph-fj/fangjun/software/protobuf-3.20.1-cmake ..
```

We have to make the following changes:

Listing 1: ./code/hello/7b4e77.diff

```
1 diff --git a/tools/CMakeLists.txt b/tools/CMakeLists.txt
2 index 0b710050..e1a5b3d0 100644
3 --- a/tools/CMakeLists.txt
4 +++ b/tools/CMakeLists.txt
5 @@ -8,6 +8,7 @@ include_directories(${CMAKE_CURRENT_BINARY_DIR})
6   protobuf_generate_cpp(CAFFE_PROTO_SRCS CAFFE_PROTO_HDRS caffe.proto)
7
8   add_executable(caffe2ncnn caffe2ncnn.cpp ${CAFFE_PROTO_SRCS} ${CAFFE_PROTO_HDRS})
9 +include_directories(${Protobuf_INCLUDE_DIR})
10
11   target_link_libraries(caffe2ncnn ${PROTOBUF_LIBRARIES})
12
13 diff --git a/tools/caffe2ncnn.cpp b/tools/caffe2ncnn.cpp
14 index 0eff756a..229cc653 100644
15 --- a/tools/caffe2ncnn.cpp
16 +++ b/tools/caffe2ncnn.cpp
17 @@ -193,7 +193,7 @@ static bool read_proto_from_binary(const char* filepath,
18   ↪google::protobuf::Message
19     google::protobuf::io::InputStream input(&fs);
20     google::protobuf::io::CodedInputStream codedstr(&input);
21
22 -    codedstr.SetTotalBytesLimit(INT_MAX, INT_MAX / 2);
23 +    codedstr.SetTotalBytesLimit(INT_MAX);
24
25     bool success = message->ParseFromCodedStream(&codedstr);
```

To install the Python package:

```
cd ncnn
mkdir build
cd build
cmake ..
make -j
cd ..
pip install .
```

## 23.2 ncnn::Mat

- Use CHW format
- Support reference counting, like a smart pointer.



## 24.1 Installation

Refer to <https://llvm.org/docs/GettingStarted.html#requirements>

<https://llvm.org/docs/GettingStarted.html#getting-a-modern-host-c-toolchain> describes how to install GCC from source.

Use of a user provided GCC:

```
mkdir build
cd build
CC=$HOME/toolchains/bin/gcc CXX=$HOME/toolchains/bin/g++ \
  cmake .. -DCMAKE_CXX_LINK_FLAGS="-Wl,-rpath,$HOME/toolchains/lib64 -L$HOME/toolchains/
  ↳lib64"
```

Useful tools that can be found in *build/bin*:

```
$ llvm-config --cxxflags
-I/ceph-fj/fangjun/open-source-2/llvm-project/llvm/include -I/ceph-fj/fangjun/open-
↳source-2/llvm-project/build/include -std=c++14 -fno-exceptions -fno-rtti -D_GNU_
↳SOURCE -D__STDC_CONSTANT_MACROS -D__STDC_FORMAT_MACROS -D__STDC_LIMIT_MACROS

$ llvm-config --libdir
/ceph-fj/fangjun/open-source-2/llvm-project/build/lib

$ llvm-config --cflags
-I/ceph-fj/fangjun/open-source-2/llvm-project/llvm/include -I/ceph-fj/fangjun/open-
↳source-2/llvm-project/build/include -D_GNU_SOURCE -D__STDC_CONSTANT_MACROS -D__STDC_
↳FORMAT_MACROS -D__STDC_LIMIT_MACROS

$ llvm-config --ldflags
-L/ceph-fj/fangjun/open-source-2/llvm-project/build/lib

$ llvm-config --src-root
/ceph-fj/fangjun/open-source-2/llvm-project/llvm

$ llvm-config --obj-root
/ceph-fj/fangjun/open-source-2/llvm-project/build

$ llvm-config --version
15.0.0git
```

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```
$ llvm-config --bindir  
/ceph-fj/fangjun/open-source-2/llvm-project/build/bin
```

## 24.2 ninja

```
pip install ninja
```

```
ninja
```

will look for the file *\$PWD/build.ninja*

```
ninja --help  
ninja -C build -j 20  
ninja -t targets  
ninja -t clean  
ninja -t cleandead  
  
ninja -v # be verbose while compiling files  
  
# suppose hello is a target  
ninja -v hello  
ninja -v -t clean hello  
  
ninja -n -v hello # dry run
```

## 24.3 Documentation

- Coding standard  
<https://llvm.org/docs/CodingStandards.html>
- LLVM Developer Policy  
<https://llvm.org/docs/DeveloperPolicy.html>
- doxygen doc  
<https://llvm.org/doxygen/>
- <http://www.aosabook.org/en/llvm.html>

## 24.4 Intermediate representation

```
clang --help
```

```
-emit-llvm  Use the LLVM representation for assembler and object files
-S          Only run preprocess and compilation steps
```

- `clang -S -emit-llvm ex.c` generates a text file `ex.ll`.
- `clang -c -emit-llvm ex.c` generates a binary file `ex.bc`.
- `llvm-dis ex.bc` generates a file `ex.ll`, which is identical with the file generated using `clang -S -emit-llvm ex.c`.`
- `llvm-as ex.ll` generates a file `ex.bc`, which is identical with the file generated using `clang -c -emit-llvm ex.c`.
- `llc ex.ll` generates the assembly file `ex.s`
- `lli ex.ll` can run this file. Use `echo $?` to see the return value.

See [https://llvm.org/devmtg/2019-04/slides/Tutorial-Bridgers-LLVM\\_IR\\_tutorial.pdf](https://llvm.org/devmtg/2019-04/slides/Tutorial-Bridgers-LLVM_IR_tutorial.pdf).

## 24.5 Install GCC

```
tar xvf gcc-12.2.0.tar.gz
cd gcc-12.2.0
./configure --prefix=/ceph-fj/fangjun/software/gcc-12.2.0
make -j 5
make install
```

```
gcc_dir=/ceph-fj/fangjun/software/gcc-12.2.0
export CC=$gcc_dir/bin/gcc
export CXX=$gcc_dir/bin/g++
export LIBRARY_PATH=$gcc_dir/lib64:$LIBRARY_PATH
export LD_LIBRARY_PATH=$gcc_dir/lib64:$LD_LIBRARY_PATH
export C_INCLUDE_PATH=$gcc_dir/include
export CPLUS_INCLUDE_PATH=$gcc_dir/include
```



## 25.1 kotlin

### 25.1.1 Install

See <https://kotlinlang.org/docs/command-line.html#run-scripts>

```
wget https://github.com/JetBrains/kotlin/releases/download/v1.7.22/kotlin-compiler-1.7.22.zip
cd $HOME/software
mkdir kotlin
cd kotlin
unzip /path/to/kotlin-compiler-1.7.22.zip
mv kotlinc 1.7.22
export PATH=$HOME/software/kotlin/1.7.22/bin:$PATH
```

#### Hello world

Create a file hello.kt:

```
fun main() {
    println("hello world")
}
```

#### Usage 1

```
kotlinc hello.kt
```

It will generate a binary hello.native:

```
$ ls -lh hello.native
-rwxr-xr-x 1 kuangfangjun root 8.1K Mar 18 2022 hello.native
```

```
readelf -d hello.native
```

It prints:

Dynamic section at offset 0xe20 contains 24 entries:

Tag	Type	Name/Value
0x0000000000000001	(NEEDED)	Shared library: [libc.so.6]

Note: It depends only on libc.

## Usage 2

```
kotlinc hello.kt -d hello.jar
# or
kotlinc hello.kt -include-runtime -d hello.jar

# It can be run using:
java -jar hello.jar
```

## 25.2 Basics

There are two tools: NDK and SDK. Each tool has a version.

Android has a concept of Android native API level.

There are three environment variables to set:

- ANDROID\_NDK\_ROOT
- ANDROID\_SDK\_ROOT
- ANDROID\_HOME

## 25.3 Installation

### 25.3.1 Install NDK on Linux (not recommended)

(Use the following SDK to install NDK)

See <https://developer.android.com/ndk/downloads/index.html>

See [https://www.cryptopp.com/wiki/Android\\_Setup\\_\(Command\\_Line\)](https://www.cryptopp.com/wiki/Android_Setup_(Command_Line)) for details.

```
wget https://dl.google.com/android/repository/android-ndk-r25-linux.zip
unzip -d /ceph-fj/fangjun/software android-ndk-r25-linux.zip
# It will create /ceph-fj/fangjun/software/android-ndk-r25
```

Other versions can be downloaded from <https://github.com/android/ndk/wiki/Unsupported-Downloads>

```
wget https://dl.google.com/android/repository/android-ndk-r24-linux.zip
unzip -d /ceph-fj/fangjun/software android-ndk-r24-linux.zip

# It will create /ceph-fj/fangjun/software/android-ndk-r24
```

Now create a symlink in /ceph-fj/fangjun/software:

```
cd /ceph-fj/fangjun/software
ln -s android-ndk-r25 android-ndk
```

Set the following environment variable:

```
export ANDROID_NDK_ROOT=/ceph-fj/fangjun/software/android-ndk
export PATH=$ANDROID_NDK_ROOT:$PATH
```

## 25.3.2 Install SDK on Linux

Download the commandline tools only from <https://developer.android.com/studio#downloads>

```
wget https://dl.google.com/android/repository/commandlinetools-linux-8512546_latest.zip
unzip -d /ceph-fj/fangjun/software/android-sdk ./commandlinetools-linux-8512546_latest.
  ↳ zip
# Everything is inside /ceph-fj/fangjun/software/android-sdk/cmdline-tools/
cd /ceph-fj/fangjun/software/android-sdk
mv cmdline-tools latest
mkdir cmdline-tools
mv latest ./cmdline-tools/
```

If we don't run `mv cmdline-tools latest`, it will throw the following error

```
$ /ceph-fj/fangjun/software/android-sdk/cmdline-tools/bin/sdkmanager --list
```

```
Error: Could not determine SDK root.
Error: Either specify it explicitly with --sdk_root= or move this package into its
  ↳ expected location: <sdk>/cmdline-tools/latest/
```

```
sdkmanager --update
sdkmanager --list
```

```
# Install the build tools
sdkmanager "platforms;android-28" "build-tools;28.0.3"
# It will create the following directories inside /ceph-fj/fangjun/software/android-sdk/
#
# build-tools, emulator, licenses, patcher, platform-tools, platforms, tools
```

```
$ sdkmanager --list_installed
Installed packages:=====] 100% Fetch remote repository...
  Path                | Version | Description                | Location
  -----            | -
  build-tools;28.0.3  | 28.0.3  | Android SDK Build-Tools 28.0.3 | build-tools/28.0.3
  emulator            | 31.3.10 | Android Emulator            | emulator
  patcher;v4          | 1       | SDK Patch Applier v4       | patcher/v4
  platform-tools      | 33.0.2  | Android SDK Platform-Tools | platform-tools
  platforms;android-28 | 6       | Android SDK Platform 28     | platforms/android-28
```

```
sdkmanager --help
yes | sdkmanager --licenses # to accept or licenses, the decision is saved in a cache
  ↳ file.
```

Set the following environment variables:

```
export ANDROID_SDK_ROOT=/ceph-fj/fangjun/software/android-sdk
export PATH=$ANDROID_SDK_ROOT/cmdline-tools/latest/bin:$PATH

export ANDROID_HOME=/ceph-fj/fangjun/software/android-sdk

# for emulator
export PATH=$ANDROID_SDK_ROOT/emulator:$PATH

# for adb
export PATH=$ANDROID_SDK_ROOT/platform-tools:$PATH

# We installed 28.0.3 before
export PATH=$ANDROID_SDK_ROOT/build-tools/28.0.3:$PATH # change it for different versions
```

Now install NDK using sdkmanager:

```
# sdkmanager --list | grep ndk
sdkmanager "ndk;21.0.6113669"
# it will download android-ndk-r21 and will generate
# android-sdk/ndk/21.0.6113669

export ANDROID_NDK_HOME=$ANDROID_SDK_ROOT/ndk/21.0.6113669
export PATH=$ANDROID_NDK_ROOT:$PATH
```

## 25.4 cmake

See

- <https://cmake.org/cmake/help/latest/manual/cmake-toolchains.7.html>
- <https://developer.android.com/ndk/guides/cmake#command-line>
- /ceph-fj/fangjun/software/android-ndk/build/cmake/android.toolchain.cmake

User provided:

- ANDROID\_NDK: Set to the path of android-ndk
- ANDROID\_ABI: armeabi-v7a, arm64-v8a, x86, x86\_64,
- ANDROID\_PLATFORM
- ANDROID\_NATIVE\_API\_LEVEL
- ANDROID\_TOOLCHAIN
- ANDROID: TRUE
- CMAKE\_SYSTEM\_NAME: Anroid
- ANDROID\_STL
- ANDROID\_HOST\_TAG

Auto generated:

- ANDROID\_NDK\_MAJOR - see android-ndk/source.properties



- ANDROID\_NDK\_MINOR - see android-ndk/source.properties
- ANDROID\_NDK\_BUILD - see android-ndk/source.properties
- ANDROID\_NDK\_REVISION - see android-ndk/source.properties
- ANDROID\_TOOLCHAIN\_ROOT
- ANDROID\_C\_COMPILER

## 25.5 hello

In this note, we describe how to build an executable, how to create an emulator, and how to run the executable in the emulator via `adb push`, `adb shell`.

Listing 1: ./code/hello/hello.cc

```

1  #include <iostream>
2
3  int main() {
4      std::cout << "hello world\n";
5      return 0;
6  }
```

Listing 2: ./code/hello/CMakeLists

```

1  cmake_minimum_required(VERSION 3.8)
2
3  project(hello)
4
5  add_executable(hello hello.cc)
```

### 25.5.1 x86

```

export ANDROID_NDK_ROOT=/ceph-fj/fangjun/software/android-ndk
cmake -DCMAKE_TOOLCHAIN_FILE=$ANDROID_NDK_ROOT/build/cmake/android.toolchain.cmake -
-DANDROID_ABI=x86 ..
```

#### Other values:

- -DANDROID\_ABI="arm64-v8a"
- -DANDROID\_ABI="armeabi-v7a"
- -DANDROID\_ARM\_NEON=ON
- -DANDROID\_PLATFORM=android-21
- -DANDROID\_PLATFORM=android-24

```

$ sdkmanager --list | grep system-images | grep x86 | grep android-28
$ sdkmanager "system-images;android-28;default;x86"

$ which avdmanager
/ceph-fj/fangjun/software/android-sdk/cmdline-tools/latest/bin/avdmanage
```

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```
$ avdmanager create avd --help
$ -k --package : Package path of the system image for this AVD
#               (e.g., 'system-images;android-19;google_apis;x86').
# -n --name     : Name of the new AVD [required]
# -b --abi      : The ABI to use for the AVD. The default is to auto-select
#               the ABI if the platform has only one ABI for its system images
# -g --tag      : The sys-img tag to use for the AVD. The default is to
#               auto-select if the platform has only one tag for its system
#               images
$ avdmanager create avd -k "system-images;android-28;default;x86" -n hello -b x86 -g
↪ default
# Use the default option [no] when it prompts:
# Do you wish to create a custom hardware profile? [no]
#
$ avdmanager delete avd -n hello # to delete it
```

```
$ avdmanager list avd
Available Android Virtual Devices:
  Name: hello
  Path: /root/fangjun/.android/avd/hello.avd
  Target: Default Android System Image
          Based on: Android 9.0 (Pie) Tag/ABI: default/x86
  Sdcard: 512 MB
```

```
emulator -avd hello -no-window -no-accel # then, open a new terminal
```

```
# push the binary from code/hello/build/hello

adb push ./code/hello/build/hello /sdcard # not able to use chmod +x in it
adb push ./code/hello/build/hello /data/local
adb shell /data/local/hello
adb shell
generic_x86:/ #
```

```
generic_x86:/ # ./data/local/hello
hello world
```

## 25.6 Android.mk

See [https://developer.android.com/ndk/guides/android\\_mk](https://developer.android.com/ndk/guides/android_mk)

### 25.6.1 hello

Listing 3: ./code/android\_mk/hello/jni/foo.cc

```
1 #include <iostream>
2 int main() { std::cout << "hello world\n"; }
```

Listing 4: ./code/android\_mk/hello/jni/Android.mk

```
1 LOCAL_PATH := $(call my-dir)
2 include $(CLEAR_VARS)
3 LOCAL_MODULE := foo
4 LOCAL_SRC_FILES := foo.cc
5 # include $(BUILD_SHARED_LIBRARY)
6 include $(BUILD_EXECUTABLE)
```

Listing 5: ./code/android\_mk/hello/jni/Application.mk

```
1 APP_ABI := x86
2 APP_STL := c++_shared
```

APP\_STL := c++\_shared is to fix the following errors:

```
ld: error: undefined symbol: std::__ndk1::cout
```

To compile:

```
cd code/android_mk/hello
ndk-build
```

It will generate two directories in hello: libs and obj..

```
adb push libs/x86/foo /data/local
adb push libs/x86/libc++_shared.so /data/local
adb shell
cd /data/local
export LD_LIBRARY_PATH=.
./foo
```

## 25.7 adb

### 25.7.1 install on macos

```
wget https://dl.google.com/android/repository/platform-tools-latest-darwin.zip  
# unzip it and you will find the binary `adb`
```

### 25.7.2 install on windows

Go to <https://adbshell.com/downloads> to download it.

### 25.7.3 install on Linux

```
wget https://dl.google.com/android/repository/platform-tools-latest-linux.zip  
# unzip it
```

## 26.1 Install

```
git clone --depth 1 https://github.com/qemu/qemu
cd qemu
```

### 26.1.1 qemu-arm

Refer to <https://github.com/Tencent/ncnn/blob/master/.github/workflows/linux-arm-cpu-gcc.yml>

```
# To generate only qemu-arm
./configure --prefix=/ceph-fj/fangjun/software/qemu/ --target-list=arm-linux-user,
↪ aarch64-linux-user --disable-system
make -j10

# It genertates the executable: ./build/qemu-arm and ./build/qemu-aarch64

# If we run `make install`, it will generate
#
# /ceph-fj/fangjun/software/qemu/bin/qemu-arm
# /ceph-fj/fangjun/software/qemu/bin/qemu-aarch64
#
# Add it to PATH and use it!
```

To run it, we have to download some cross-compile toochain, e.g,

Go to <https://developer.arm.com/tools-and-software/open-source-software/developer-tools/gnu-toolchain/gnu-a/downloads/8-3-2019-0> to download the toolchain.

```
mkdir /ceph-fj/fangjun/software
cd /ceph-fj/fangjun/software
tar xvf /path/to/gcc-arm-8.3-2019.03-x86_64-arm-linux-gnueabihf.tar.xz

export PATH=/ceph-fj/fangjun/software/gcc-arm-8.3-2019.03-x86_64-arm-linux-gnueabihf/bin:
↪ $PATH
```

If we have built an executable using the above toolchain, we can run it with qemu-arm:

```
./build/qemu-arm /path/to/sherpa-ncnn
```

It throws the following error:

```
qemu-arm: Unable to reserve 0xffff000 bytes of virtual address space at
0x1000 (Success) for use as guest address space (check your virtual memory
ulimit setting, min_mmap_addr or reserve less using -R option)
```

We can use

```
./build/qemu-arm -B 0x10000000 /path/to/sherpa-ncnn
```

which throws the following new error:

```
(py38) kuangfangjun:qemu$ find /ceph-fj/fangjun/software/gcc-arm-8.3-2019.03-x86_64-arm-
↳ linux-gnueabi/ -name "ld-linux-armhf.so.3"
/ceph-fj/fangjun/software/gcc-arm-8.3-2019.03-x86_64-arm-linux-gnueabi/
↳ arm-linux-gnueabi/libc/lib/ld-linux-armhf.so.3
(py38) kuangfangjun:qemu$ export QEMU_LD_PREFIX=/ceph-fj/fangjun/software/gcc-arm-8.3-
↳ 2019.03-x86_64-arm-linux-gnueabi/
arm-linux-gnueabi/libc
```

Now we can restart:

```
./build/qemu-arm -B 0x10000000 /path/to/sherpa-ncnn
```

```
export PATH=/ceph-fj/fangjun/software/qemu/bin:$PATH
export QEMU_LD_PREFIX=/ceph-fj/fangjun/software/gcc-arm-8.3-2019.03-x86_64-arm-linux-
↳ gnueabi/
arm-linux-gnueabi/libc

qemu-arm -B 0x10000000 ./build-arm-linux-gnueabi/bin/sherpa-ncnn \
./sherpa-ncnn-2022-09-05/tokens.txt \
./sherpa-ncnn-2022-09-05/bar/encoder_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.param \
./sherpa-ncnn-2022-09-05/bar/encoder_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.bin \
./sherpa-ncnn-2022-09-05/bar/decoder_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.param \
./sherpa-ncnn-2022-09-05/bar/decoder_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.bin \
./sherpa-ncnn-2022-09-05/bar/joiner_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.param \
./sherpa-ncnn-2022-09-05/bar/joiner_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.bin \
./test_wavs/1221-135766-0002.wav
```

## 26.1.2 qemu-aarch64

```
wget https://releases.linaro.org/components/toolchain/binaries/latest-7/aarch64-linux-
↳ gnu/gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu.tar.xz
cd /ceph-fj/fangjun/software
tar xvf /path/to/gcc-linaro-7.5.0-2019.12-x86_64_aarch64-linux-gnu.tar.xz
```

```
export PATH=/ceph-fj/fangjun/software/qemu/bin:$PATH
export QEMU_LD_PREFIX=/ceph-fj/fangjun/software/gcc-linaro-7.5.0-2019.12-x86_64_aarch64-
↳ linux-gnu/aarch64-linux-gnu/libc

qemu-aarch64 -B 0x10000000 ./build-aarch64-linux-gnu/bin/sherpa-ncnn \
./sherpa-ncnn-2022-09-05/tokens.txt \
./sherpa-ncnn-2022-09-05/bar/encoder_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.param \
./sherpa-ncnn-2022-09-05/bar/encoder_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.bin \
./sherpa-ncnn-2022-09-05/bar/decoder_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.param \
```

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```
./sherpa-ncnn-2022-09-05/bar/decoder_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.bin \  
./sherpa-ncnn-2022-09-05/bar/joiner_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.param \  
./sherpa-ncnn-2022-09-05/bar/joiner_jit_trace-v2-iter-468000-avg-16-pnnx.ncnn.bin \  
./test_wavs/1221-135766-0002.wav
```





## 27.1 Basics

### 27.1.1 Extract part of a wave

```
# offset 2 seconds, length 0.195 seconds  
sox in.mp3 out.mp3 trim 2 0.195
```

### 27.1.2 Fix broken waves

```
sox --ignore-length corrupted.wav fixed.wav
```



## 28.1 Install

Refer to <https://mnn-docs.readthedocs.io/en/latest/compile/engine.html>

```
./schema/generate.sh
mkdir build
cd build
cmake -DMNN_BUILD_CONVERTER=ON -DMNN_SUPPORT_DEPRECATED_OP=OFF -DMNN_BUILD_TORCH=ON ..
make -j 10
```

---

**Note:** Use CPLUS\_INCLUDE\_PATH and C\_INCLUDE\_PATH to add additional paths for searching.

---

### 28.1.1 Python

See <https://mnn-docs.readthedocs.io/en/latest/compile/pymnn.html>

To build a python package, use:

```
cd pymnn/pip_package/
python3 ./build_deps.py
python3 setup.py bdist_wheel --version 2.1.1
# We can get the version from include/MNN/MNNDefine.h
# or we can give it an arbitrary version string.
pip install ./dist/MNN-2.1.1-cp38-cp38-linux_x86_64.whl
cd $HOME
python3 -c "import MNN; print(dir(MNN))"
```

## 28.2 Hello

Create a simple torchscript model:

Listing 1: ./code/hello/ex1.py

```
1 #!/usr/bin/env python3
2
3 import torch
```

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```

4
5
6 class Foo(torch.nn.Module):
7     def forward(self, x):
8         return torch.nn.functional.relu(x)
9
10
11 f = Foo()
12 x = torch.rand(2)
13 m = torch.jit.trace(f, x)
14 m.save("ex1.pt")
15 print(m.graph)

```

```
MNNConvert -f TORCH --modelFile ./ex1.pt --MNNModel ex1.mnn --bizCode MNN
```

It prints:

```

Start to Convert Other Model Format To MNN Model...
Start to Optimize the MNN Net...
inputTensors : [ x.1, ]
outputTensors: [ 2, ]
Converted Success!

```

We can use:

```
netron ex1.mnn --port 6006
```

to view it:

```
Serving 'ex1.mnn' at http://localhost:6006
```

To convert the model to json, use:

```
MNNDump2Json ./ex1.mnn ./ex1.json
```

which generates:

Listing 2: ./code/hello/ex1.json

```

1 { "bizCode": "MNN", "extraInfo":
2   { "version": "2.1.1" }
3   , "oplists":
4   [
5     { "main_type": "Input", "main":
6       { "dtype": "DT_FLOAT", "dformat": "NCHW" }
7       , "name": "x.1", "outputIndexes":
8       [ 0 ]
9       , "type": "Input", "defaultDimentionFormat": "NHWC" }
10    ,
11    { "inputIndexes":
12      [ 0 ]
13      , "main_type": "Relu", "main":
14      { "slope": 0.0 }

```

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```

15 , "name": "2", "outputIndexes":
16 [ 1 ]
17 , "type": "ReLU", "defaultDimentionFormat": "NCHW" }
18 ]
19 , "outputName":
20 [ "2" ]
21 , "preferForwardType": "CPU", "sourceType": "TORCH", "tensorName":
22 [ "x.1", "2" ]
23 , "tensorNumber": 0, "usage": "INFERENCE", "mnn_uuid": "d24b26b1-14c8-42cb-9ce1-
  ↪ 2a9b867714e9" }

```

To convert ex1.json back to a .mnn file, use:

```
MNNRevert2Buffer ex1.json ex1.mnn
```

To show the information of the model:

```
MNNConvert --framework MNN --modelFile ./ex1.mnn --info
```

It prints:

```

Model default dimensionFormat is NCHW
Model Inputs:
[ x.1 ]: dimensionFormat: NCHW, size: [ ], type is float
Model Outputs:
[ 2 ]
Model Version: 2.1.1

```

To run it with MNN in Python:

Listing 3: ./code/hello/test-ex1-mnn.py

```

1  #!/usr/bin/env python3
2
3  import numpy as np
4  import MNN
5  import torch
6
7
8  def main():
9      interpreter = MNN.Interpreter("ex1.mnn")
10
11      config = {}
12      config["precision"] = "low" # low, high, normal
13      config["backend"] = "CPU"
14      # config["thread"] = 1
15      session = interpreter.createSession(config)
16
17      # a = torch.tensor([1, -2.5, 3.2], dtype=torch.float32)
18      # b = a.numpy()
19
20      input_tensor = interpreter.getSessionInput(session)
21      interpreter.resizeTensor(input_tensor, (3,))

```

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```
22 interpreter.resizeSession(session)
23 print("input_tensor.getShape()", input_tensor.getShape())
24
25 input_data = MNN.expr.const(
26     np.array([1, -2.5, 3.2], dtype=np.float32),
27     (3,),
28     MNN.expr.NCHW,
29     MNN.expr.float,
30 )
31 input_tensor.copyFrom(MNN.Tensor(input_data))
32 print("input_tensor.getNumpyData()", input_tensor.getNumpyData())
33
34 interpreter.runSession(session)
35
36 output_tensor = interpreter.getSessionOutput(session)
37 print("output_tensor.getNumpyData()", output_tensor.getNumpyData())
38
39 output_data = MNN.Tensor(
40     output_tensor.getShape(), MNN.Halide_Type_Float, MNN.Tensor_DimensionType_Caffe
41 )
42 output_tensor.copyToHostTensor(output_data)
43 print("output_data.getNumpyData()", output_data.getNumpyData())
44
45
46 if __name__ == "__main__":
47     main()
```

It prints:

```
input_tensor.getShape() (3,)
input_tensor.getNumpyData() [ 1. -2.5  3.2]
output_tensor.getNumpyData() [1.  0.  3.2]
output_data.getNumpyData() [1.  0.  3.2]
```

## 29.1 References

- <https://www.intel.com/content/www/us/en/docs/intrinsics-guide/index.html>  
All APIs for intrinsics with examples
- 15-418/15-618: Parallel Computer Architecture and Programming, Spring 2018: Schedule  
<https://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/15418-s18/www/schedule.html>
- How to Write Fast Code 18-645 (CMU, ECE)  
<https://users.ece.cmu.edu/~pueschel/teaching/18-645-CMU-spring08/course.html>
- <http://spcl.inf.ethz.ch/Teaching/2018-dphpc/lectures/lecture8-simd.pdf>

### SSE:

- 128-bit
- `__m128`, `__m128d`
- `_mm_load_ps`, `_mm_add_pd`

### AVX:

- 256-bit
- `__m256`, `__mm256d`
- `_mm256_load_ps`, `_mm256_add_pd`

### AVX512:

- 512-bit

## 29.2 Headers

- `mmintrin.h` MMX
- `xmmintrin.h` SSE
- `emmintrin.h`, SSE2
- `pmmintrin.h`, SSE3
- `tmmintrin.h`, SSSE3
- `smmintrin.h`, SSE4.1

- `nmmintrin.h`, SSE4.2
- `ammintrin.h`, SSE4A
- `wmmmintrin.h`, AES
- `immintrin.h`, AVX

## 29.3 SSE

The header file is `xmmintrin.h`, it is in `/usr/lib/gcc/x86_64-linux-gnu/7/include`. There is also a file `mmmintrin.h`.

## 29.4 avx

SSE4 data types:

- `__m128`, 4 floats
- `__m128d`, 2 doubles
- `__m128i`, it depends, can be 16 8-bit, 8 16-bit, 4 32-bit, 2 64-bit

AVX2 data types:

- `__m256`, 8 floats
- `__m256d`, 4 doubles
- `__m256i`, 32 8-bit, 16 16-bit, 8 32-bit, 4 64-bit

Listing 1: `./code/avx/main.cc`

```

1  #include <cassert>
2  #include <immintrin.h>
3
4  // ps means packed single precision
5  static void TestLoadStore() {
6      alignas(16) float a[4] = {1, 2, 3, 4};
7      alignas(16) float b[4];
8      __m128 f = _mm_load_ps(a);
9      // f = _mm_loadu_ps(a); // if a not aligned
10     _mm_store_ps(b, f);
11     // _mm_storeu_ps(b, f); // if b is not aligned
12     assert(b[0] == a[0]);
13     assert(b[1] == a[1]);
14     assert(b[2] == a[2]);
15     assert(b[3] == a[3]);
16
17     // set manually
18     f = _mm_set_ps(a[3], a[2], a[1], a[0]);
19     _mm_store_ps(b, f);
20     assert(b[0] == a[0]);
21     assert(b[1] == a[1]);
22     assert(b[2] == a[2]);

```

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```

23  assert(b[3] == a[3]);
24
25  // for double
26  alignas(32) double k[4] = {1, 2, 3, 4};
27  __m256d d = _mm256_load_pd(k);
28  // d = _mm256_loadu_pd(k); // if k is not aligned
29  alignas(32) double m[4];
30  _mm256_store_pd(m, d);
31  // _mm256_storeu_pd(m, d); // if m is not aligned
32  assert(m[0] == k[0]);
33  assert(m[1] == k[1]);
34  assert(m[2] == k[2]);
35  assert(m[3] == k[3]);
36
37  d = _mm256_set_pd(k[3], k[2], k[1], k[0]);
38  _mm256_store_pd(m, d);
39  assert(m[0] == k[0]);
40  assert(m[1] == k[1]);
41  assert(m[2] == k[2]);
42  assert(m[3] == k[3]);
43 }
44
45 static void TestLoadStore1() {
46     float a = 10;
47     float b[4];
48     __m128 f = _mm_load_ps1(&a);
49     _mm_store_ps(b, f);
50     assert(b[0] == a);
51     assert(b[1] == a);
52     assert(b[2] == a);
53     assert(b[3] == a);
54 }
55
56 static void TestAdd() {
57     float a[4] = {1, 2, 3, 4};
58     float b[4] = {10, 20, 30, 40};
59     __m128 f = _mm_load_ps(a);
60     __m128 g = _mm_load_ps(b);
61     __m128 h = _mm_add_ps(f, g);
62     float c[4];
63     _mm_store_ps(c, h);
64     assert(c[0] == a[0] + b[0]);
65     assert(c[1] == a[1] + b[1]);
66     assert(c[2] == a[2] + b[2]);
67     assert(c[3] == a[3] + b[3]);
68 }
69
70 static void AddIndex1(double *x, int32_t n) {
71     for (int32_t i = 0; i < n; ++i) {
72         x[i] = x[i] + i;
73     }
74 }

```

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```

75
76 // assume n % 4 == 0
77 static void AddIndex2(double *x, int32_t n) {
78     assert(n % 4 == 0);
79     __m256d index, x_vec;
80     for (int32_t i = 0; i < n; i += 4) {
81         x_vec = _mm256_load_pd(x + i);
82         // x_vec[0] = x[i]
83         // x_vec[1] = x[i+1]
84         // x_vec[2] = x[i+2]
85         // x_vec[3] = x[i+3]
86
87         index = _mm256_set_pd(i + 3, i + 2, i + 1, i);
88         // index[0] = i
89         // index[1] = i+1
90         // index[2] = i+2
91         // index[3] = i+3
92
93         x_vec = _mm256_add_pd(x_vec, index);
94         // x_vec[0] = x_vec[0] + index[0]
95         // x_vec[1] = x_vec[1] + index[1]
96         // x_vec[2] = x_vec[2] + index[2]
97         // x_vec[3] = x_vec[3] + index[3]
98
99         _mm256_store_pd(x + i, x_vec);
100        // (x+i)[0] = x_vec[0]
101        // (x+i)[1] = x_vec[1]
102        // (x+i)[2] = x_vec[2]
103        // (x+i)[3] = x_vec[3]
104    }
105 }
106
107 static void TestAddIndex() {
108     alignas(32) double a[64];
109     alignas(32) double b[64];
110     for (int32_t i = 0; i != 64; ++i) {
111         a[i] = b[i] = i;
112     }
113     AddIndex1(a, 64);
114     AddIndex2(b, 64);
115     for (int32_t i = 0; i != 64; ++i) {
116         assert(a[i] == b[i]);
117     }
118 }
119
120 int main() {
121     TestLoadStore();
122     TestLoadStore1();
123     TestAdd();
124     TestAddIndex();
125     return 0;
126 }

```

## 30.1 Install

```
git clone https://github.com/chriskohlhoff/asio/  
cd asio/asio  
./autogen.sh  
./configure --prefix=/ceph-fj/fangjun/software/asio  
make -j 10  
make install
```

It will create include and lib/pkgconfig/asio.pc inside /ceph-fj/fangjun/software/asio. Note that it is a header only library.

## 30.2 Hello

<https://think-async.com/Asio/asio-1.24.0/doc/asio/tutorial/tuttimer1.html>

Listing 1: ./code/Makefile

```
1 CXXFLAGS := -I /ceph-fj/fangjun/software/asio/include -pthread  
2  
3 srcs := $(shell find . -type f -name "*.cc" -printf "%f ")  
4 targets :=$(srcs:%.cc=%)  
5  
6 all: $(targets)  
7  
8 %: %.cc  
9     $(CXX) $(CXXFLAGS) -o $@ $<  
10  
11  
12 .PHONY: clean  
13 clean:  
14     $(RM) $(targets)
```

Listing 2: ./code/1-timer-synchronous.cc

```
1 #include "asio.hpp"  
2 #include <iostream>  
3
```

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```
4 int main() {
5     asio::io_context io;
6     std::cout << "sleep for 1 second\n";
7     asio::steady_timer t(io, asio::chrono::seconds(1));
8     t.wait();
9     std::cout << "hello world\n";
10    return 0;
11 }
```

Listing 3: ./code/2-timer-asynchronous.cc

```
1 #include "asio.hpp"
2 #include <iostream>
3
4 void print(const asio::error_code &) { std::cout << "done\n"; }
5
6 int main() {
7     asio::io_context io;
8     std::cout << "sleep for 1 seconds\n";
9     asio::steady_timer t(io, asio::chrono::seconds(1));
10
11     t.async_wait(&print);
12     t.async_wait(&print);
13     io.run();
14     return 0;
15 }
```

Listing 4: ./code/3-timer-async-bind-argument.cc

```
1 #include "asio.hpp"
2 #include <iostream>
3
4 void print(const asio::error_code &ec, asio::steady_timer *t, int *counter) {
5     if (*counter < 3) {
6         std::cout << *counter << "\n";
7         *counter += 1;
8         t->expires_at(t->expiry() + asio::chrono::seconds(1));
9         t->async_wait(
10             [t, counter](const asio::error_code &e) { print(e, t, counter); });
11     }
12 }
13
14 int main() {
15     asio::io_context io;
16     asio::steady_timer t(io, asio::chrono::seconds(1));
17     int counter = 0;
18
19     // use a lambda to pass extra parameters
20     t.async_wait(
21         [&t, &counter](const asio::error_code &ec) { print(ec, &t, &counter); });
22     io.run();
23     return 0;
24 }
```

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24 }

Listing 5: ./code/4-timer-async-member-function.cc

```

1  #include "asio.hpp"
2  #include <iostream>
3
4  class printer {
5  public:
6      printer(asio::io_context &io)
7          : t_(io, asio::chrono::seconds(1)), counter_(0) {
8          t_.async_wait([this](const asio::error_code &ec) { print(ec); });
9      }
10
11     void print(const asio::error_code &ec) {
12         if (counter_ < 6) {
13             std::cout << counter_ << "\n";
14             counter_ += 1;
15             t_.async_wait([this](const asio::error_code &e) { this->print(e); });
16         }
17     }
18
19 private:
20     asio::steady_timer t_;
21     int counter_;
22 };
23 int main() {
24     asio::io_context io;
25     printer p(io);
26     io.run();
27     return 0;
28 }

```

Listing 6: ./code/5-timer-async-thread-non-synchronization.cc

```

1  #include "asio.hpp"
2  #include <iostream>
3  #include <thread>
4
5  class printer {
6  public:
7      printer(asio::io_context &io)
8          : t1_(io, asio::chrono::seconds(1)), t2_(io, asio::chrono::seconds(1)) {
9          t1_.async_wait([this](const asio::error_code &e) { print1(e); });
10         t2_.async_wait([this](const asio::error_code &e) { print2(e); });
11     }
12
13     void print1(const asio::error_code &ec) {
14         if (counter_ < 8) {
15             std::cout << "print1 id: " << std::this_thread::get_id() << ", counter "
16                 << counter_ << "\n";
17             counter_ += 1;

```

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```

18     t1_.expires_at(t1_.expiry() + asio::chrono::seconds(1));
19     t1_.async_wait([this](const asio::error_code &e) { print1(e); });
20 }
21 }
22
23 void print2(const asio::error_code &ec) {
24     if (counter_ < 8) {
25         std::cout << "print2 id: " << std::this_thread::get_id() << ", counter "
26             << counter_ << "\n";
27         counter_ += 1;
28         t2_.expires_at(t2_.expiry() + asio::chrono::seconds(1));
29         t2_.async_wait([this](const asio::error_code &e) { print2(e); });
30     }
31 }
32
33 private:
34     asio::steady_timer t1_;
35     asio::steady_timer t2_;
36     int counter_ = 0;
37 };
38
39 int main() {
40     asio::io_context io;
41     printer p(io);
42     std::thread t([&io]() { io.run(); }); // NOTE: print1() and print2() can run
43                                         // either in t or in the main thread
44     io.run();
45     t.join();
46 }
47
48 #if 0
49 (py38) kuangfangjun:code$ ./5-timer-async-thread-non-synchronization
50 print1 id: print2 id: 140164266059584, counter 0
51 140164247860992, counter 1
52 print1 id: 140164266059584, counter 2
53 print2 id: 140164247860992, counter 3
54 print1 id: 140164266059584, counter 4
55 print2 id: 140164247860992, counter 5
56 print1 id: 140164266059584, counter 6
57 print2 id: 140164247860992, counter 7
58 (py38) kuangfangjun:code$ ./5-timer-async-thread-non-synchronization
59 print2 id: print1 id: 140191018206976, counter 140191036405568, counter 0
60 0
61 print1 id: 140191018206976, counter print2 id: 2
62 140191036405568, counter 3
63 print1 id: 140191018206976, counter 4
64 print2 id: 140191036405568, counter 5
65 print1 id: 140191018206976, counter 6
66 print2 id: 140191036405568, counter 7
67 #endif

```

Listing 7: ./code/6-timer-async-thread-with-synchronization.cc

```

1  #include "asio.hpp"
2  #include <iostream>
3  #include <thread>
4
5  class printer {
6  public:
7      printer(asio::io_context &io)
8          : strand_(asio::make_strand(io)), t1_(io, asio::chrono::seconds(1)),
9            t2_(io, asio::chrono::seconds(1)) {
10         t1_.async_wait(asio::bind_executor(
11             strand_, [this](const asio::error_code &e) { print1(e); }));
12         t2_.async_wait(asio::bind_executor(
13             strand_, [this](const asio::error_code &e) { print2(e); }));
14     }
15
16     void print1(const asio::error_code &ec) {
17         if (counter_ < 8) {
18             std::cout << "print1 id: " << std::this_thread::get_id() << ", counter "
19                 << counter_ << "\n";
20             counter_ += 1;
21             t1_.expires_at(t1_.expiry() + asio::chrono::seconds(1));
22             t1_.async_wait([this](const asio::error_code &e) { print1(e); });
23         }
24     }
25
26     void print2(const asio::error_code &ec) {
27         if (counter_ < 8) {
28             std::cout << "print2 id: " << std::this_thread::get_id() << ", counter "
29                 << counter_ << "\n";
30             counter_ += 1;
31             t2_.expires_at(t2_.expiry() + asio::chrono::seconds(1));
32             t2_.async_wait([this](const asio::error_code &e) { print2(e); });
33         }
34     }
35
36 private:
37     asio::strand<asio::io_context::executor_type> strand_;
38     asio::steady_timer t1_;
39     asio::steady_timer t2_;
40     int counter_ = 0;
41 };
42
43 int main() {
44     asio::io_context io;
45     printer p(io);
46     std::thread t([&io]() { io.run(); }); // NOTE: print1() and print2() can run
47                                         // either in t or in the main thread
48     io.run();
49     t.join();
50 }

```

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```

51 #if 0
52 (py38) kuangfangjun:code$ ./6-timer-async-thread-with-synchronization
53 print1 id: 140648598263616, counter 0
54 print2 id: 140648598263616, counter 1
55 print1 id: 140648580065024, counter 2
56 print2 id: 140648598263616, counter 3
57 print1 id: 140648580065024, counter 4
58 print2 id: 140648598263616, counter 5
59 print1 id: 140648580065024, counter 6
60 print2 id: 140648598263616, counter 7
61 (py38) kuangfangjun:code$ ./6-timer-async-thread-with-synchronization
62 print1 id: 139671509145408, counter 0
63 print2 id: 139671509145408, counter 1
64 print1 id: 139671490946816, counter 2
65 print2 id: 139671509145408, counter 3
66 print1 id: 139671490946816, counter 4
67 print2 id: 139671509145408, counter 5
68 print1 id: 139671490946816, counter 6
69 print2 id: 139671509145408, counter 7
70 #endif

```

Listing 8: ./code/7-daytime-sync-client.cc

```

1  #include "asio.hpp"
2  #include <array>
3  #include <iostream>
4
5  using asio::ip::tcp;
6  int main(int argc, char *argv[]) {
7      try {
8          if (argc != 2) {
9              std::cerr << "Usage: client <host>" << std::endl;
10             return 1;
11         }
12
13         asio::io_context io;
14         tcp::resolver resolver(io);
15
16         tcp::resolver::results_type endpoints =
17             resolver.resolve(argv[1], "daytime");
18
19         tcp::socket socket(io);
20         asio::connect(socket, endpoints);
21
22         for (;;) {
23             std::array<char, 128> buf;
24             asio::error_code ec;
25             size_t len = socket.read_some(asio::buffer(buf), ec);
26             if (ec == asio::error::eof) {
27                 break;
28             } else if (ec) {
29                 throw asio::system_error(ec);

```

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```

30     }
31     std::cout.write(buf.data(), len);
32 }
33 } catch (std::exception &e) {
34     std::cerr << "exception: " << e.what() << "\n";
35 }
36 return 0;
37 }

```

Listing 9: ./code/8-daytime-sync-server.cc

```

1  #include "asio.hpp"
2  #include <ctime>
3  #include <iostream>
4  #include <string>
5
6  using asio::ip::tcp;
7  std::string make_daytime_string() {
8      using namespace std;
9      time_t now = time(0);
10     return ctime(&now);
11 }
12
13 int main() {
14     try {
15         asio::io_context io;
16         // need sudo permission to bind port 13
17         tcp::acceptor acceptor(io, tcp::endpoint(tcp::v4(), 13));
18         std::cout << "started\n";
19         for (;;) {
20             tcp::socket socket(io);
21             acceptor.accept(socket);
22
23             auto message = make_daytime_string();
24             asio::error_code ec;
25             asio::write(socket, asio::buffer(message), ec);
26         }
27     } catch (std::exception &e) {
28         std::cout << "Exception: " << e.what() << "\n";
29     }
30     return 0;
31 }

```

Listing 10: ./code/9-daytime-async-server.cc

```

1  #include "asio.hpp"
2  #include <ctime>
3  #include <iostream>
4  #include <memory>
5
6  using asio::ip::tcp;
7

```

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```

8  std::string make_daytime_string() {
9      using namespace std;
10     time_t now = time(0);
11     return ctime(&now);
12 }
13
14 class tcp_connection : public std::enable_shared_from_this<tcp_connection> {
15 public:
16     using pointer = std::shared_ptr<tcp_connection>;
17
18     static pointer create(asio::io_context &io) {
19         return pointer(new tcp_connection(io));
20         // return std::make_shared<tcp_connection>(io);
21     }
22
23     tcp::socket &socket() { return socket_; }
24
25     void start() {
26         message_ = make_daytime_string();
27         auto p = shared_from_this();
28         asio::async_write(
29             socket_, asio::buffer(message_),
30             [p](const asio::error_code &ec, size_t bytes_transferred) {
31                 p->handle_write(ec, bytes_transferred);
32             });
33     }
34
35 private:
36     tcp_connection(asio::io_context &io) : socket_(io) {}
37
38     void handle_write(const asio::error_code & /*ec*/,
39                     size_t /*bytes_transferred*/) {}
40
41     tcp::socket socket_;
42     std::string message_;
43 };
44
45 class tcp_server {
46 public:
47     tcp_server(asio::io_context &io)
48         : io_(io), acceptor_(io, tcp::endpoint(tcp::v4(), 13)) {
49         start_accept();
50     }
51
52 private:
53     void start_accept() {
54         tcp_connection::pointer new_connection = tcp_connection::create(io_);
55         acceptor_.async_accept(new_connection->socket(),
56                               [this, new_connection](const asio::error_code &ec) {
57                                   this->handle_accept(new_connection, ec);
58                               });
59     }

```

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```
60 void handle_accept(tcp_connection::pointer new_connection,  
61                   const asio::error_code &ec) {  
62     if (!ec) {  
63         new_connection->start();  
64     }  
65     start_accept();  
66 }  
67  
68 asio::io_context io_;  
69 tcp::acceptor acceptor_;  
70 };  
71  
72 int main() {  
73     try {  
74         asio::io_context io;  
75         tcp_server server(io);  
76         io.run();  
77     } catch (std::exception &e) {  
78         std::cout << "Exception: " << e.what();  
79     }  
80     return 0;  
81 }
```



## WEBSOCKETPP

### 31.1 Install

```
git clone https://github.com/zaphoyd/websocketpp
cd websocketpp
mkdir build
cmake -DCMAKE_INSTALL_PREFIX=/ceph-fj/fangjun/software/websocketpp ..
make -j install
```

### 31.2 hello

Listing 1: ./code/hello/Makefile

```
1 CXXFLAGS := -DASIO_STANDALONE
2 CXXFLAGS += -I/ceph-fj/fangjun/software/asio/include
3 CXXFLAGS += -I/ceph-fj/fangjun/software/websocketpp/include
4 CXXFLAGS += -std=c++14
5 LDFLAGS += -pthread
6
7 main: main.o uri.o
8     $(CXX) -o $@ $^ $(LDFLAGS)
9
10 %.o: %.cc
11     $(CXX) -c $(CXXFLAGS) -o $@ $<
12
13 clean:
14     $(RM) *.o main
```

Listing 2: ./code/hello/main.cc

```
1 #include "websocketpp/client.hpp"
2 #include "websocketpp/config/asio_no_tls_client.hpp"
3 #include <assert.h>
4 #include <iostream>
5 #include <memory>
6 #include <string>
7 #include <thread>
8
```

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```

9 using client = websocketpp::client<websocketpp::config::asio_client>;
10
11 class connection_metadata {
12 public:
13     using ptr = std::shared_ptr<connection_metadata>;
14     connection_metadata(int32_t id, websocketpp::connection_hdl hdl,
15                         std::string uri)
16         : m_id(id), m_hdl(hdl), m_status("Connecting"), m_uri(uri),
17           m_server("N/A") {}
18     void on_open(client *c, websocketpp::connection_hdl hdl) {
19         m_status = "Open";
20         client::connection_ptr con = c->get_con_from_hdl(hdl);
21         m_server = con->get_response_header("Server");
22
23         // the type of con->get_response() is defined in
24         // websocketpp/http/response.hpp
25         assert(con->get_response().get_version() == "HTTP/1.1");
26     #if 0
27         // header_list is a std::map<std::string, std::string>
28         auto header_list = con->get_response().get_headers();
29         for (const auto &it : header_list) {
30             std::cout << it.first << ": " << it.second << "\n";
31         }
32         /*
33         Connection: upgrade
34         Date: Wed, 05 Oct 2022 11:33:39 GMT
35         Sec-WebSocket-Accept: QvLQVaiZn5YWerU3s15SuDWypjo=
36         Server: nginx
37         Upgrade: websocket
38         */
39     #endif
40         assert(con->get_response().get_body() == "");
41     }
42
43     void on_fail(client *c, websocketpp::connection_hdl hdl) {
44         m_status = "Failed";
45         client::connection_ptr con = c->get_con_from_hdl(hdl);
46         m_server = con->get_response_header("Server");
47         m_error_reason = con->get_ec().message();
48     }
49
50     void on_close(client *c, websocketpp::connection_hdl hdl) {
51         m_status = "Closed";
52         client::connection_ptr con = c->get_con_from_hdl(hdl);
53         std::ostringstream os;
54         os << "close code: " << con->get_remote_close_code() << " ("
55           << websocketpp::close::status::get_string(con->get_remote_close_code())
56           << "), close reason: " << con->get_remote_close_reason();
57         m_error_reason = os.str();
58     }
59
60     websocketpp::connection_hdl get_hdl() const { return m_hdl; }

```

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```

61  int32_t get_id() const { return m_id; }
62  const std::string &get_status() const { return m_status; }
63
64  friend std::ostream &operator<<(std::ostream &out,
65                                  const connection_metadata &data);
66
67 private:
68  int32_t m_id;
69  websocketpp::connection_hdl m_hdl;
70  std::string m_status;
71  std::string m_uri;
72  std::string m_server;
73  std::string m_error_reason;
74 };
75
76 std::ostream &operator<<(std::ostream &out, const connection_metadata &data) {
77     out << "> URI: " << data.m_uri << "\n"
78     << "> Status: " << data.m_status << "> Remote Server: "
79     << (data.m_server.empty() ? "None Specified" : data.m_server) << "\n"
80     << "> Error/close reason: "
81     << (data.m_error_reason.empty() ? "N/A" : data.m_error_reason);
82     return out;
83 }
84
85 class websocket_endpoint {
86 public:
87     websocket_endpoint() : m_next_id(0) {
88         m_endpoint.clear_access_channels(websocketpp::log::alevel::all);
89         m_endpoint.clear_error_channels(websocketpp::log::elevel::all);
90
91         m_endpoint.init_asio();
92         m_endpoint.start_perpetual();
93
94         m_thread.reset(new std::thread(&client::run, &m_endpoint));
95     }
96
97     ~websocket_endpoint() {
98         m_endpoint.stop_perpetual();
99         for (auto it = m_connection_list.begin(); it != m_connection_list.end();
100             ++it) {
101             if (it->second->get_status() != "Open") {
102                 continue;
103             }
104
105             std::cout << "> Closing connection " << it->second->get_id() << std::endl;
106             websocketpp::lib::error_code ec;
107             m_endpoint.close(it->second->get_hdl(),
108                             websocketpp::close::status::going_away, "", ec);
109             if (ec) {
110                 std::cout << "> Error closing connection " << it->second->get_id()
111                 << ": " << ec.message() << std::endl;
112             }

```

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```

113     }
114     m_thread->join();
115 }
116
117 int32_t connect(std::string uri) {
118     websocketpp::lib::error_code ec;
119     client::connection_ptr con = m_endpoint.get_connection(uri, ec);
120     if (ec) {
121         std::cout << "> Connect initialization error: " << ec.message()
122                 << std::endl;
123         return -1;
124     }
125     int32_t new_id = m_next_id++;
126     connection_metadata::ptr metadata_ptr(
127         new connection_metadata(new_id, con->get_handle(), uri));
128     m_connection_list[new_id] = metadata_ptr;
129
130     // see websocketpp/connection.hpp
131     con->set_open_handler(
132         [metadata_ptr = metadata_ptr, this](websocketpp::connection_hdl hdl) {
133             metadata_ptr->on_open(&m_endpoint, hdl);
134         });
135
136     // see websocketpp/connection.hpp
137     con->set_fail_handler(
138         [metadata_ptr = metadata_ptr, this](websocketpp::connection_hdl hdl) {
139             metadata_ptr->on_fail(&m_endpoint, hdl);
140         });
141
142     con->set_close_handler(
143         [metadata_ptr = metadata_ptr, this](websocketpp::connection_hdl hdl) {
144             metadata_ptr->on_close(&m_endpoint, hdl);
145         });
146
147     m_endpoint.connect(con);
148
149     return new_id;
150 }
151
152 connection_metadata::ptr get_metadata(int32_t id) const {
153     auto metadata_it = m_connection_list.find(id);
154     if (metadata_it == m_connection_list.end()) {
155         return connection_metadata::ptr();
156     } else {
157         return metadata_it->second;
158     }
159 }
160
161 void close(int32_t id, websocketpp::close::status::value code,
162           const std::string &reason = "") {
163     websocketpp::lib::error_code ec;
164     auto metadata_it = m_connection_list.find(id);

```

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```

165     if (metadata_it == m_connection_list.end()) {
166         std::cout << "> No connection found with id " << id << std::endl;
167         return;
168     }
169
170     m_endpoint.close(metadata_it->second->get_hdl(), code, reason, ec);
171     if (ec) {
172         std::cout << "> Error initiating close: " << ec.message() << std::endl;
173     }
174 }
175
176 private:
177     client m_endpoint;
178     std::shared_ptr<std::thread> m_thread;
179     std::map<int32_t, connection_metadata::ptr> m_connection_list;
180     int32_t m_next_id;
181 };
182
183 void test_uri();
184
185 int main() {
186     test_uri();
187     // return 0;
188
189     bool done = false;
190     std::string input;
191     websocket_endpoint endpoint;
192
193     while (true) {
194         std::cout << "Enter command: ";
195         std::getline(std::cin, input);
196         if (input == "quit") {
197             done = true;
198         } else if (input == "help") {
199             std::cout << "\nCommand List:\n"
200                 << "connect <ws uri>\n"
201                 << "show <connection_id>\n"
202                 << "close <connection_id> <close_code> <close_reason>\n"
203                 << "help: Display the help and exit\n"
204                 << "quit: Exit the program\n"
205                 << "\n";
206         } else if (input.substr(0, 7) == "connect") {
207             int32_t id = endpoint.connect(input.substr(8));
208             if (id != -1) {
209                 std::cout << "Created connection with id " << id << "\n";
210             }
211         } else if (input.substr(0, 5) == "close") {
212             std::stringstream ss(input);
213             std::string cmd;
214             int32_t id;
215             int32_t close_code = websocketpp::close::status::normal;
216             std::string reason;

```

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```

217     ss >> cmd >> id >> close_code;
218     std::getline(ss, reason);
219     endponit.close(id, close_code, reason);
220 } else if (input.substr(0, 4) == "show") {
221     int32_t id = atoi(input.substr(5).c_str());
222     connection_metadata::ptr metadata = endponit.get_metadata(id);
223     if (metadata) {
224         std::cout << *metadata << std::endl;
225     } else {
226         std::cout << "Unknown connection id " << id << std::endl;
227     }
228 } else {
229     std::cout << "Unrecognized command\n";
230 }
231 if (done)
232     break;
233 }
234 return 0;
235 }
236 // connect ws://websocket-echo.com
237 // close 0 1001 example message

```

Listing 3: ./code/hello/uri.cc

```

1  #include "websocketpp/uri.hpp"
2  #include <assert.h>
3  #include <iostream>
4
5  static void check_valid_ipv4() {
6      std::string s = "10.192.168.1";
7      bool b = websocketpp::uri_helper::ipv4_literal(s.begin(), s.end());
8      assert(b == true);
9
10     s = "256.192.168.1";
11     b = websocketpp::uri_helper::ipv4_literal(s.begin(), s.end());
12     assert(b == false);
13 }
14
15 static void check_uri() {
16     websocketpp::uri uri("ws://localhost:81");
17     assert(uri.str() == "ws://localhost:81/");
18     assert(uri.get_valid() == true);
19     assert(uri.is_ipv6_literal() == false);
20     assert(uri.get_secure() == false);
21     assert(uri.get_scheme() == "ws");
22     assert(uri.get_host() == "localhost");
23     assert(uri.get_port() == 81);
24     assert(uri.get_port_str() == "81");
25     assert(uri.get_host_port() == "localhost:81");
26     assert(uri.get_authority() == "localhost:81");
27     assert(uri.get_resource() == "/");
28     assert(uri.get_query() == "");

```

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```
29 }
30
31 static void check_uri2() {
32     websocketpp::uri uri("wss://localhost/foo/bar?hello=12");
33     assert(uri.str() == "wss://localhost/foo/bar?hello=12");
34     assert(uri.get_valid() == true);
35     assert(uri.is_ipv6_literal() == false);
36     assert(uri.get_secure() == true);
37     assert(uri.get_scheme() == "wss");
38     assert(uri.get_host() == "localhost");
39     assert(uri.get_port() == 443);
40     assert(uri.get_port_str() == "443");
41     assert(uri.get_host_port() == "localhost");
42     assert(uri.get_authority() == "localhost:443");
43     assert(uri.get_resource() == "/foo/bar?hello=12");
44     assert(uri.get_query() == "hello=12");
45 }
46
47 void test_uri() {
48     check_valid_ipv4();
49     check_uri();
50     check_uri2();
51 }
```



## OPERATING SYSTEMS

### 32.1 macos

Copy content to the clipboard:

```
cat result.txt | pbcopy
```