
notes

fangjun

Oct 14, 2022

CONTENTS:

1	Sphinx	3
1.1	Setup	3
1.2	How to include code from a file	4
1.3	Link	4
1.3.1	hello	5
2	git	7
2.1	Commands	7
2.1.1	rev-parse	7
3	docker	9
3.1	Installation	9
3.1.1	macos	9
4	LaTeX	11
4.1	TikZ	11
4.1.1	Basics	11
5	Kaldi	13
5.1	Decoding	13
6	bash	15
6.1	sort	15
6.2	echo	15
6.3	ffmpeg	15
6.3.1	Convert format	15
6.3.2	References	16
7	CUDA	17
7.1	Installation	17
7.1.1	CUDA 10.1.243	17
7.1.2	CUDA 11.0.3	17
7.1.3	CUDA 11.3.1	18
7.1.4	CUDA 11.5.2	18
7.1.5	CUDA 11.6.1	18
8	torch	19
8.1	torch.load and torch.save	19
8.2	torch.gather	19
8.3	DDP	20
8.3.1	Initialization	20

8.4	TorchScript	20
8.4.1	doxygen doc	20
8.4.2	Hello	21
8.4.3	Load in C++	26
8.4.4	ArrayRef	28
8.4.5	ScalarType	30
8.4.6	TypeMeta	31
8.4.7	torch::Device	32
8.4.8	TensorOptions	34
8.4.9	Tensor Creation	35
8.4.10	Tensor	37
8.4.11	intrusive_ptr	43
8.4.12	optional	43
8.4.13	PackedSequence	43
8.4.14	ivalue	44
8.4.15	method	47
8.4.16	type	48
8.4.17	trace	50
8.4.18	Node	54
8.4.19	symbol	56
8.4.20	graph	56
8.5	Logical operations	58
8.6	Note	59
8.7	Quantization	59
8.7.1	Internals	59
8.7.2	torch.quantize_per_tensor	61
8.7.3	quantize_per_tensor_dynamic	62
8.7.4	torch.quantize_per_channel	63
8.7.5	Observer	65
8.7.6	Hello	66
8.7.7	References	67
8.8	android	67
8.8.1	References	67
8.9	onnx	67
8.9.1	Install	67
8.9.2	Hello	68
8.9.3	Multiple models	70
8.9.4	References	72
8.10	nn.LSTM	72
9	Python	75
9.1	asyncio	75
9.1.1	asyncio.Future	75
9.1.2	iterator	75
9.1.3	yield	75
9.1.4	Hello World	75
9.1.5	References	76
9.1.6	TODOs	76
9.2	argv	77
9.3	TODO	77
9.4	time	77
9.5	Numbers	77
9.5.1	binary representation	77
9.6	str	78

9.6.1	format	78
9.7	enum	79
9.7.1	Hello	79
9.8	socket	81
9.8.1	AddressFamily	81
9.8.2	SocketKind	82
9.8.3	struct sockaddr_in	83
9.8.4	AddressInfo	84
9.8.5	inet_pton	84
9.8.6	inet_ntop	89
9.8.7	Echo Server and Client	93
9.8.8	TODOs	96
10	java	97
10.1	Install	97
10.1.1	formatter	97
10.1.2	JDK	97
10.2	Hello world	98
10.3	Reference	99
11	javascript	101
11.1	Hello world	101
11.1.1	array	101
11.1.2	class	102
11.2	node	102
11.3	TODOs	103
12	HTML	105
12.1	Hello world	105
12.1.1	comments	105
12.1.2	images	105
12.1.3	ordered lists	105
12.1.4	unordered lists	106
12.1.5	links	106
12.2	References	106
13	css	107
13.1	Hello world	107
13.1.1	comment	107
13.1.2	Selector	107
13.2	References	108
14	pybind11	109
14.1	GIL	109
15	Protocol Buffers	111
15.1	Installation	111
15.1.1	C++	111
15.1.2	Install with cmake	119
15.2	Hello	119
15.2.1	hello.proto	119
15.2.2	makefile	120
15.2.3	hello.pb.h	121
15.2.4	hello.pb.cc	142

16 gRPC	163
16.1 Install	163
17 lwn.net	165
17.1 TODOs	165
18 Linker and Loader	167
18.1 References	167
18.2 Questions	168
19 espnet	169
19.1 aishell	169
19.1.1 AM training	169
20 cmake	171
20.1 Tutorials	171
20.2 Install	171
21 huggingface	173
21.1 spaces	173
21.1.1 Install client API	173
21.1.2 gradio	173
22 EECS E6870 Speech Recognition	175
22.1 Notes	175
23 ncnn	177
23.1 Hello	177
23.2 ncnn::Mat	178
24 LLVM	179
24.1 Installation	179
24.2 ninja	180
24.3 Documentation	180
24.4 Intermediate representation	181
24.5 Install GCC	181
25 Android	183
25.1 Basics	183
25.2 Installation	183
25.2.1 Install NDK on Linux (not recommended)	183
25.2.2 Install SDK on Linux	184
25.3 cmake	185
25.4 hello	186
25.4.1 x86	186
25.5 Android.mk	187
25.5.1 hello	188
25.6 adb	188
25.6.1 install on macos	188
25.6.2 install on windows	189
25.6.3 install on Linux	189
26 qemu	191
26.1 Install	191
26.1.1 qemu-arm	191

27	sox	193
27.1	Basics	193
27.1.1	Extract part of a wave	193
27.1.2	Fix broken waves	193
28	MNN	195
28.1	Install	195
28.1.1	Python	195
28.2	Hello	195
29	SIMD	199
29.1	References	199
29.2	Headers	199
29.3	SSE	200
29.4	avx	200
30	asio	203
30.1	Install	203
31	websocketpp	205
31.1	Install	205
31.2	hello	205
32	Operating systems	211
32.1	macos	211

Download this website in a single [pdf file](#).

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 = {
```

(continues on next page)

(continued from previous page)

```
'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
```

(continues on next page)

(continued from previous page)

(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>

CUDA

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 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
```

7.1.3 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
```

7.1.4 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
```

7.1.5 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
```

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
```

(continues on next page)

(continued from previous page)

```
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.

`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)

```

(continues on next page)

(continued from previous page)

```

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)

```

(continues on next page)

(continued from previous page)

```

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):

```

(continues on next page)

(continued from previous page)

```

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.

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;

```

(continues on next page)

(continued from previous page)

```

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;

```

(continues on next page)

(continued from previous page)

```

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),

```

(continues on next page)

(continued from previous page)

```

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/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 }

```

(continues on next page)

(continued from previous page)

```

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);

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```
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);

```

(continues on next page)

(continued from previous page)

```

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}));

```

(continues on next page)

(continued from previous page)

```

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

```

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 42: ./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} ]

```

(continues on next page)

(continued from previous page)

```

32  unsorted_indices:  2
33      0
34      1
35  [ CPULongType{3} ]
36  */

```

The output is

Listing 43: ./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 44: ./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 =

```

(continues on next page)

(continued from previous page)

```

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));
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]));

```

(continues on next page)

(continued from previous page)

```

74 // Note: We can pass a vector directly
75 r = m.run_method("forward", v);
76 TORCH_CHECK(torch::allclose(r.toTensor(), v[0] + v[1]));
77
78
79 r = m.run_method("forward", ilist); // also OK
80 TORCH_CHECK(torch::allclose(r.toTensor(), v[0] + v[1]));
81 }
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::ivar::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::ivar::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

```

(continues on next page)

(continued from previous page)

```

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
134 torch::IValue  ivalue2(ilist2);
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 45: ./code/method/main.cc

```

1 #include "torch/script.h"
2
3 static void TestHello() {

```

(continues on next page)

(continued from previous page)

```

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");
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.h - https://github.com/pytorch/pytorch/blob/master/aten/src/ATen/core/jit_type_base.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 46: ./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"));

```

(continues on next page)

(continued from previous page)

```

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();
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

```

(continues on next page)

(continued from previous page)

```

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());
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 47: ./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

```

(continues on next page)

(continued from previous page)

```

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__', '__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 48: ./code/trace/ex1.py

```

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

```

(continues on next page)

(continued from previous page)

```

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
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 49: ./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
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

```

(continues on next page)

(continued from previous page)

```

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):
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");

```

(continues on next page)

(continued from previous page)

```

102     TORCH_CHECK(torch::jit::attr::name == c10::attr::name);
103
104     torch::jit::Function &function = class_type->getMethod(function_name);
105     if (!function.isGraphFunction()) {
106         std::cout << function_name << " is not a graph function"
107             << "\n";
108         continue;
109     }
110     std::string class_type_str =
111         torch::jit::removeTorchMangle(class_type->str());
112     // remove __torch__, which is 10 characters long
113     std::string no_torch_class_type_str = class_type_str.substr(10);
114 }
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

8.4.20 graph

Listing 50: ./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);

```

(continues on next page)

(continued from previous page)

```

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();
25     return 0;
26 }

```

Listing 51: ./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

```

(continues on next page)

(continued from previous page)

```

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)
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 52: ./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 53: ./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

```
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 54: ./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 }
```

(continues on next page)

(continued from previous page)

```

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 `_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,

```

(continues on next page)

(continued from previous page)

```

        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 55: ./code/observer/ex0.py

```

1  #!/usr/bin/env python3
2
3  import torch
4  from torch.aot.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 56: ./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

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/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/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

8.9.2 Hello

Listing 57: ./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 58: ./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 59: ./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)

```

(continues on next page)

(continued from previous page)

```

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 60: ./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()

```

(continues on next page)

(continued from previous page)

```

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.]]

```

(continues on next page)

(continued from previous page)

```

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
- 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 61: ./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,

```

(continues on next page)

(continued from previous page)

```

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"]

```

(continues on next page)

(continued from previous page)

```
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
```

(continues on next page)

(continued from previous page)

```
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_OAlIhXziw&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>
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
```

(continues on next page)

(continued from previous page)

```
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'>

```

(continues on next page)

(continued from previous page)

```

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))
```

(continues on next page)

(continued from previous page)

```

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://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

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

Listing 13: ./code/inet_pton_impl.c

```

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

```

(continues on next page)

(continued from previous page)

```

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      {

```

(continues on next page)

(continued from previous page)

```

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;

```

(continues on next page)

(continued from previous page)

```

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)

```

(continues on next page)

(continued from previous page)

```

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. */

```

(continues on next page)

(continued from previous page)

```

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

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 }

```

(continues on next page)

(continued from previous page)

```

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

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);

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```

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     /*

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```
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

```

(continues on next page)

(continued from previous page)

```
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
```

10.2 Hello world

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
//
class Hello {
    public static void main(String[] args) {
        System.out.println("hello world");
    }
} // There is no ';' here
```

Listing 2: EqualTest.java

```
class EqualTest {
    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
    }
}
```

10.3 Reference

- <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) {
```

(continues on next page)

(continued from previous page)

```
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 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
3. Google font: <https://fonts.google.com/> and 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 `` or `<p id="my-id">`
- class: e.g., `.my-class` selects `` and `<p class="my-class">`
- attribute: e.g., `img[src]` selects `` but not ``

See 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 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

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)
```


(continued from previous page)

```

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'

```

(continues on next page)

(continued from previous page)

```

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'

```

(continues on next page)

(continued from previous page)

```

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 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/io'
/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 '/'
↳ root/fangjun/software/protobuf-3.20.1/include/google/protobuf/stubs'
85 /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'

```

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```

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>

```

(continues on next page)

(continued from previous page)

```

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.");

```

(continues on next page)

(continued from previous page)

```

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_
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_
133         ↪ ID::UnknownFieldSet>();
134     }

```

(continues on next page)

(continued from previous page)

```

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);

```

(continues on next page)

(continued from previous page)

```

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();

```

(continues on next page)

(continued from previous page)

```

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);

```

(continues on next page)

(continued from previous page)

```

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 static constexpr int kIndexInFileMessages =
324     1;
325
326 friend void swap(Person& a, Person& b) {
327     a.Swap(&b);
328 }
329 inline void Swap(Person* other) {
330     if (other == this) return;
331 #ifdef PROTOBUF_FORCE_COPY_IN_SWAP
332     if (GetOwningArena() != nullptr &&
333         GetOwningArena() == other->GetOwningArena()) {

```

(continues on next page)

(continued from previous page)

```

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);

```

(continues on next page)

(continued from previous page)

```

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;

```

(continues on next page)

(continued from previous page)

```

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:

```

(continues on next page)

(continued from previous page)

```

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::
↳ ID::internal::ConstantInitialized);
521
522     AddressBook(const AddressBook& from);
523     AddressBook(AddressBook&& from) noexcept
524         : AddressBook() {
525         *this = ::std::move(from);
526     }
527
528     inline AddressBook& operator=(const AddressBook& from) {
529         CopyFrom(from);
530         return *this;
531     }
532
533     inline AddressBook& operator=(AddressBook&& from) noexcept {
534         if (this == &from) return *this;

```

(continues on next page)

(continued from previous page)

```

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);

```

(continues on next page)

(continued from previous page)

```

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;

```

(continues on next page)

(continued from previous page)

```

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 #ifdef __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 {

```

(continues on next page)

(continued from previous page)

```

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) {

```

(continues on next page)

(continued from previous page)

```

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 }

```

(continues on next page)

(continued from previous page)

```

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 {

```

(continues on next page)

(continued from previous page)

```

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 {

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```

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 {

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```

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 };

```

(continues on next page)

(continued from previous page)

```

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_

```

(continues on next page)

(continued from previous page)

```

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,

```

(continues on next page)

(continued from previous page)

```

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) {

```

(continues on next page)

(continued from previous page)

```

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;

```

(continues on next page)

(continued from previous page)

```

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);

```

(continues on next page)

(continued from previous page)

```

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 }

```

(continues on next page)

(continued from previous page)

```

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());

```

(continues on next page)

(continued from previous page)

```

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) {

```

(continues on next page)

(continued from previous page)

```

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>()) {

```

(continues on next page)

(continued from previous page)

```

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 }

```

(continues on next page)

(continued from previous page)

```

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);

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```

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

```

(continues on next page)

(continued from previous page)

```

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]);

```

(continues on next page)

(continued from previous page)

```

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 }

```

(continues on next page)

(continued from previous page)

```

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);

```

(continues on next page)

(continued from previous page)

```

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,

```

(continues on next page)

(continued from previous page)

```

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);

```

(continues on next page)

(continued from previous page)

```
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/
- <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
```


CMAKE

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
```

(continues on next page)

(continued from previous page)

```
$ 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.

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 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`

25.2 Installation

25.2.1 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
```

25.2.2 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
```

(continues on next page)

(continued from previous page)

```
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
```

25.3 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: Android
- 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

25.4 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)
```

25.4.1 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/avdmanager

$ avdmanager create avd --help
$ -k --package : Package path of the system image for this AVD
```

(continues on next page)

(continued from previous page)

```
# (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
```

25.5 Android.mk

See https://developer.android.com/ndk/guides/android_mk

25.5.1 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
```

25.6 adb

25.6.1 install on macos

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

25.6.2 install on windows

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

25.6.3 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 --
↪disable-system
make -j10

# It generates the executable: ./build/qemu-arm

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

To run it, we have to download some cross-compile toolchain, 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-gnueabi.tar.xz

export PATH=/ceph-fj/fangjun/software/gcc-arm-8.3-2019.03-x86_64-arm-linux-gnueabi/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 0x100000000 /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/f/ -name "ld-linux-armhf.so.3"
/ceph-fj/fangjun/software/gcc-arm-8.3-2019.03-x86_64-arm-linux-gnueabi/f/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/f/arm-linux-gnueabi/libc
```

Now we can restart:

```
./build/qemu-arm -B 0x100000000 /path/to/sherpa-ncnn
```


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
```

(continues on next page)

(continued from previous page)

```

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 }

```

(continues on next page)

(continued from previous page)

```

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,))

```

(continues on next page)

(continued from previous page)

```
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`, `__m256d`
- `_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 `xmmmintrin.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]);
```

(continues on next page)

(continued from previous page)

```

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 }

```

(continues on next page)

(continued from previous page)

```

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.

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 <iostream>
4 #include <memory>
5 #include <string>
6 #include <thread>
7
8 using client = websocketpp::client<websocketpp::config::asio_client>;
```

(continues on next page)

(continued from previous page)

```

9
10 class connection_metadata {
11 public:
12     using ptr = std::shared_ptr<connection_metadata>;
13     connection_metadata(int32_t id, websocketpp::connection_hdl hdl,
14                         std::string uri)
15         : m_id(id), m_hdl(hdl), m_status("Connecting"), m_uri(uri),
16           m_server("N/A") {}
17     void on_open(client *c, websocketpp::connection_hdl hdl) {
18         m_status = "Open";
19         client::connection_ptr con = c->get_con_from_hdl(hdl);
20         m_server = con->get_response_header("Server");
21     }
22
23     void on_fail(client *c, websocketpp::connection_hdl hdl) {
24         m_status = "Failed";
25         client::connection_ptr con = c->get_con_from_hdl(hdl);
26         m_server = con->get_response_header("Server");
27         m_error_reason = con->get_ec().message();
28     }
29
30     friend std::ostream &operator<<(std::ostream &out,
31                                     const connection_metadata &data);
32
33 private:
34     int32_t m_id;
35     websocketpp::connection_hdl m_hdl;
36     std::string m_status;
37     std::string m_uri;
38     std::string m_server;
39     std::string m_error_reason;
40 };
41
42 std::ostream &operator<<(std::ostream &out, const connection_metadata &data) {
43     out << "> URI: " << data.m_uri << "\n"
44         << "> Status: " << data.m_status << "> Remote Server: "
45         << (data.m_server.empty() ? "None Specified" : data.m_server) << "\n"
46         << "> Error/close reason: "
47         << (data.m_error_reason.empty() ? "N/A" : data.m_error_reason);
48     return out;
49 }
50
51 class websocket_endpoint {
52 public:
53     websocket_endpoint() : m_next_id(0) {
54         m_endpoint.clear_access_channels(websocketpp::log::alevel::all);
55         m_endpoint.clear_error_channels(websocketpp::log::elevel::all);
56
57         m_endpoint.init_asio();
58         m_endpoint.start_perpetual();
59
60         m_thread.reset(new std::thread(&client::run, &m_endpoint));

```

(continues on next page)

(continued from previous page)

```

61 }
62
63 int32_t connect(std::string uri) {
64     websocketpp::lib::error_code ec;
65     client::connection_ptr con = m_endpoint.get_connection(uri, ec);
66     if (ec) {
67         std::cout << "> Connect initialization error: " << ec.message()
68             << std::endl;
69         return -1;
70     }
71     int32_t new_id = m_next_id++;
72     connection_metadata::ptr metadata_ptr(
73         new connection_metadata(new_id, con->get_handle(), uri));
74     m_connection_list[new_id] = metadata_ptr;
75
76     con->set_open_handler(
77         [metadata_ptr = metadata_ptr, this](websocketpp::connection_hdl hdl) {
78             metadata_ptr->on_open(&m_endpoint, hdl);
79         });
80
81     con->set_fail_handler(
82         [metadata_ptr = metadata_ptr, this](websocketpp::connection_hdl hdl) {
83             metadata_ptr->on_fail(&m_endpoint, hdl);
84         });
85     m_endpoint.connect(con);
86
87     return new_id;
88 }
89
90 connection_metadata::ptr get_metadata(int32_t id) const {
91     auto metadata_it = m_connection_list.find(id);
92     if (metadata_it == m_connection_list.end()) {
93         return connection_metadata::ptr();
94     } else {
95         return metadata_it->second;
96     }
97 }
98
99 private:
100     client m_endpoint;
101     std::shared_ptr<std::thread> m_thread;
102     std::map<int32_t, connection_metadata::ptr> m_connection_list;
103     int32_t m_next_id;
104 };
105
106 void test_uri();
107
108 int main() {
109     test_uri();
110     return 0;
111
112     bool done = false;

```

(continues on next page)

(continued from previous page)

```

113 std::string input;
114 websocket_endpoint endponit;
115
116 while (true) {
117     std::cout << "Enter command: ";
118     std::getline(std::cin, input);
119     if (input == "quit") {
120         done = true;
121     } else if (input == "help") {
122         std::cout << "\nCommand List:\n"
123             << "connect <ws uri>\n"
124             << "show <connection_id>\n"
125             << "help: Display the help and exit\n"
126             << "quit: Exit the program\n"
127             << "\n";
128     } else if (input.substr(0, 7) == "connect") {
129         int32_t id = endponit.connect(input.substr(8));
130         if (id != -1) {
131             std::cout << "Created connection with id " << id << "\n";
132         }
133     } else if (input.substr(0, 4) == "show") {
134         int32_t id = atoi(input.substr(5).c_str());
135         connection_metadata::ptr metadata = endponit.get_metadata(id);
136         if (metadata) {
137             std::cout << *metadata << std::endl;
138         } else {
139             std::cout << "Unknown connection id " << id << std::endl;
140         }
141     } else {
142         std::cout << "Unrecognized command\n";
143     }
144     if (done)
145         break;
146 }
147 return 0;
148 }
149 // Use connect ws://websocket-echo.com
150 // for testing

```

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());

```

(continues on next page)

(continued from previous page)

```
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() == "");
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
```