
notes

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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 = {
```

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

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

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

1.2 How to include code from a file

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

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

1.3 Link

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

1.3.1 hello

Here is a link to *hello*.

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

```
hello
```

```
-----
```

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


This page describes commonly used git commands.

2.1 Commands

2.1.1 rev-parse

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

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

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

```
/xxx/notes
```

The following shows its usage in a Python script:

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

import subprocess

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

It can also be used in bash script:

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

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

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

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

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

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



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

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}

BASH

6.1 sort

Sort files in the folder `t`. The filename has the patten `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
```


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 DDP

8.1.1 Initialization

8.2 TorchScript

8.2.1 Hello

See https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.html.

`torch.jit.script` as a decorator

Listing 1: `./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
```

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```

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 2: ./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)
7     assert isinstance(adder_func, torch.jit.ScriptFunction)
8     print(adder_func.graph)
9     print(adder_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 3: ./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()

```

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```

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 """

```

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 4: `./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 foobar(self, x: torch.Tensor):
7         return x + 3
8
9     def foo(self, x: torch.Tensor):
10        return self.foobar(x)
11
12    def bar(self, x: torch.Tensor):
13        return self.p - x
14
15    @torch.jit.export
16    def baz(self, x: torch.Tensor):

```

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```

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 """

```

8.2.2 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 5: `./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__))')

```

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```

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()
22 ↪ else "no")')
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 6: `./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");

```

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```

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} ]

```

8.2.3 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 7: `./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 8: `./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 9: `./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 10: ./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`

8.2.4 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 11: ./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 12: ./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 13: ./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;  
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 14: ./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 15: ./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`.

8.2.5 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 16: ./code/type-meta/main.cc (Check size)

```

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

```

Constructors

Listing 17: ./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);

```

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```
9  
10 TORCH_CHECK(t.name() == "int");  
11 }
```

Operations with ScalarType

Listing 18: ./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);  
}
```

8.2.6 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 19: ./code/device/main.cc

```

1 void TestDeviceType() {
2     torch::DeviceType d = torch::kCPU;
3     std::ostringstream os;
4     os << d;
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 20: ./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);

```

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```

36 TORCH_CHECK(d.index() == 1);
37 }

```

8.2.7 TensorOptions

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

Constructors (not recommended)

Listing 21: ./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 22: ./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),

```

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```

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

```

Methods

Listing 23: ./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 }

```

8.2.8 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 24: `./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 25: ./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 26: ./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
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 27: ./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 }

```

8.2.9 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 28: ./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 10
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);
16
17    TORCH_CHECK(t.size(0) == 2);
18    TORCH_CHECK(t.size(1) == 3);
19    TORCH_CHECK(t.size(2) == 4);
20    TORCH_CHECK(t.sizes() == torch::ArrayRef<int64_t>({2, 3, 4}));
21
22    t = t.contiguous();
23    TORCH_CHECK(t.stride(0) == 3 * 4);
24    TORCH_CHECK(t.stride(1) == 4);
25    TORCH_CHECK(t.stride(2) == 1);

```

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```

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

```

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```

78  t = t.cpu();
79
80  torch::TensorOptions opts = t.options();
81  TORCH_CHECK(opts.device() == t.device());
82  }

```

8.2.10 intrusive_ptr

8.2.11 optional

8.2.12 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 29: ./code/packed-sequence/main.cc

```

1  static void TestPadPackedSequence() {
2      torch::Tensor t = torch::tensor({
3          {{10, 20, 30}, {0, 0, 0}},
4          {{1, 2, 3}, {4, 5, 6}},
5      });
6      torch::Tensor lengths = torch::tensor({1, 2});
7      torch::nn::utils::rnn::PackedSequence packed_seq =
8          torch::nn::utils::rnn::pack_padded_sequence(
9              t, lengths, /*batch_first*/ true, /*enforce_sorted*/ false);
10     std::cout << "data: " << packed_seq.data() << "\n";
11     std::cout << "batch_sizes: " << packed_seq.batch_sizes() << "\n";
12     std::cout << "sorted_indices: " << packed_seq.sorted_indices() << "\n";
13     std::cout << "unsorted_indices: " << packed_seq.unsorted_indices() << "\n";
14 }

```

The output is

Listing 30: ./code/packed-sequence/main.cc

```

1  /*
2  data:   1   2   3
3         10  20  30
4         4   5   6
5  [ CPULongType{3,3} ]
6  batch_sizes: 2
7              1
8  [ CPULongType{2} ]
9  sorted_indices: 1
10              0

```

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```
11 [ CPULongType{2} ]  
12 unsorted_indices: 1  
13 0  
14 [ CPULongType{2} ]  
15 */
```

8.2.13 ivalue

9.1 asyncio

9.1.1 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
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())
```

9.1.2 References

- PEP 234 – Iterators
<https://peps.python.org/pep-0234/>
- Why does defining `__getitem__` on a class make it iterable in python?
<https://localcoder.org/why-does-defining-getitem-on-a-class-make-it-iterable-in-python>
- PEP 255 – Simple Generators
<https://peps.python.org/pep-0255/>
- Curious Course on Coroutines and Concurrency
https://www.youtube.com/watch?v=Z_OAllhXziw&ab_channel=DavidBeazley
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.

9.1.3 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)
```

Python with zeroMQ (c extension)

9.3 time

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

9.4 Numbers

9.4.1 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)) # 0b100000000
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
14
15 assert 1_000 == 1000
16 assert 1_000_000 == 1000000
```

9.5 str

9.5.1 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
```

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```
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"
```


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++.

11.2 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:

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/
```

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```

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

```

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```

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

```

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```

76 /usr/bin/install -c -m 644 google/protobuf/util/delimited_message_util.h google/
↳ protobuf/util/field_comparator.h google/protobuf/util/field_mask_util.h google/
↳ protobuf/util/json_util.h google/protobuf/util/message_differencer.h google/protobuf/
↳ util/time_util.h google/protobuf/util/type_resolver.h google/protobuf/util/type_
77 ↳ resolver_util.h '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/util'
78 /usr/bin/install -c -m 644 google/protobuf/io/coded_stream.h google/protobuf/io/gzip_
↳ stream.h google/protobuf/io/io_win32.h google/protobuf/io/printer.h google/protobuf/io/
↳ strtod.h google/protobuf/io/tokenizer.h google/protobuf/io/zero_copy_stream.h google/
↳ protobuf/io/zero_copy_stream_impl.h google/protobuf/io/zero_copy_stream_impl_lite.h '/'
79 ↳ root/fangjun/software/protobuf-3.20.1/include/google/protobuf/io'
/bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
↳ csharp'
80 /usr/bin/install -c -m 644 google/protobuf/compiler/csharp/csharp_doc_comment.h google/
↳ protobuf/compiler/csharp/csharp_generator.h google/protobuf/compiler/csharp/csharp_
↳ names.h google/protobuf/compiler/csharp/csharp_options.h '/root/fangjun/software/
↳ protobuf-3.20.1/include/google/protobuf/compiler/csharp'
81 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/compiler/
↳ php'
82 /usr/bin/install -c -m 644 google/protobuf/compiler/php/php_generator.h '/root/fangjun/
↳ software/protobuf-3.20.1/include/google/protobuf/compiler/php'
83 /bin/mkdir -p '/root/fangjun/software/protobuf-3.20.1/include/google/protobuf/stubs'
84 /usr/bin/install -c -m 644 google/protobuf/stubs/bytestream.h google/protobuf/stubs/
↳ callback.h google/protobuf/stubs/casts.h google/protobuf/stubs/common.h google/
↳ protobuf/stubs/hash.h google/protobuf/stubs/logging.h google/protobuf/stubs/macros.h
↳ google/protobuf/stubs/map_util.h google/protobuf/stubs/mutex.h google/protobuf/stubs/
↳ once.h google/protobuf/stubs/platform_macros.h google/protobuf/stubs/port.h google/
↳ protobuf/stubs/status.h google/protobuf/stubs/stl_util.h google/protobuf/stubs/
↳ stringpiece.h google/protobuf/stubs/strutil.h google/protobuf/stubs/template_util.h '/'
↳ 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'

```

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```

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

```

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

```

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

```

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```

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

```

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```

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

```

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```

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

```

15.2 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 ];

```

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```
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
```

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```

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>
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_
↳ 2eproto;
48 namespace tutorial {
49 class AddressBook;
50 struct AddressBookDefaultTypeInternal;
51 extern AddressBookDefaultTypeInternal _AddressBook_default_instance_;
52 class Person;
53 struct PersonDefaultTypeInternal;
54 extern PersonDefaultTypeInternal _Person_default_instance_;
55 class Person_PhoneNumber;
56 struct Person_PhoneNumberDefaultTypeInternal;
57 extern Person_PhoneNumberDefaultTypeInternal _Person_PhoneNumber_default_instance_;
58 } // namespace tutorial
59 PROTOBUF_NAMESPACE_OPEN
60 template<> ::tutorial::AddressBook* Arena::CreateMaybeMessage<::tutorial::AddressBook>
↳ (Arena*);
61 template<> ::tutorial::Person* Arena::CreateMaybeMessage<::tutorial::Person>(Arena*);
62 template<> ::tutorial::Person_PhoneNumber* Arena::CreateMaybeMessage<::tutorial::Person_
↳ PhoneNumber>(Arena*);
63 PROTOBUF_NAMESPACE_CLOSE
64 namespace tutorial {
65
66 enum Person_PhoneType : int {
67     Person_PhoneType_MOBILE = 0,
68     Person_PhoneType_HOME = 1,
69     Person_PhoneType_WORK = 2
70 };

```

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```

71 bool Person_PhoneType_IsValid(int value);
72 constexpr Person_PhoneType Person_PhoneType_PhoneType_MIN = Person_PhoneType_MOBILE;
73 constexpr Person_PhoneType Person_PhoneType_PhoneType_MAX = Person_PhoneType_WORK;
74 constexpr int Person_PhoneType_PhoneType_ARRAYSIZE = Person_PhoneType_PhoneType_MAX + 1;
75
76 const ::PROTOBUF_NAMESPACE_ID::EnumDescriptor* Person_PhoneType_descriptor();
77 template<typename T>
78 inline const std::string& Person_PhoneType_Name(T enum_t_value) {
79     static_assert(::std::is_same<T, Person_PhoneType>::value ||
80         ::std::is_integral<T>::value,
81         "Incorrect type passed to function Person_PhoneType_Name.");
82     return ::PROTOBUF_NAMESPACE_ID::internal::NameOfEnum(
83         Person_PhoneType_descriptor(), enum_t_value);
84 }
85 inline bool Person_PhoneType_Parse(
86     ::PROTOBUF_NAMESPACE_ID::ConstStringParam name, Person_PhoneType* value) {
87     return ::PROTOBUF_NAMESPACE_ID::internal::ParseNamedEnum<Person_PhoneType>(
88         Person_PhoneType_descriptor(), name, value);
89 }
90 // =====
91
92 class Person_PhoneNumber final :
93     public ::PROTOBUF_NAMESPACE_ID::Message /* @@protoc_insertion_point(class_
94     ↪ definition:tutorial.Person.PhoneNumber) */ {
95 public:
96     inline Person_PhoneNumber() : Person_PhoneNumber(nullptr) {}
97     ~Person_PhoneNumber() override;
98     explicit PROTOBUF_CONSTEXPR Person_PhoneNumber(::PROTOBUF_NAMESPACE_ID::
99     ↪ ID::internal::ConstantInitialized);
100
101     Person_PhoneNumber(const Person_PhoneNumber& from);
102     Person_PhoneNumber(Person_PhoneNumber&& from) noexcept
103         : Person_PhoneNumber() {
104         *this = ::std::move(from);
105     }
106
107     inline Person_PhoneNumber& operator=(const Person_PhoneNumber& from) {
108         CopyFrom(from);
109         return *this;
110     }
111
112     inline Person_PhoneNumber& operator=(Person_PhoneNumber&& from) noexcept {
113         if (this == &from) return *this;
114         if (GetOwningArena() == from.GetOwningArena())
115             && GetOwningArena() != nullptr
116         #endif // !PROTOBUF_FORCE_COPY_IN_MOVE
117         ) {
118             InternalSwap(&from);
119         } else {
120             CopyFrom(from);
121         }
122         return *this;

```

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```

121 }
122
123 inline const ::PROTOBUF_NAMESPACE_ID::UnknownFieldSet& unknown_fields() const {
124     return _internal_metadata_.unknown_fields<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>
↪ (::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance);
125 }
126 inline ::PROTOBUF_NAMESPACE_ID::UnknownFieldSet* mutable_unknown_fields() {
127     return _internal_metadata_.mutable_unknown_fields<::PROTOBUF_NAMESPACE_
↪ ID::UnknownFieldSet>();
128 }
129
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

```

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```

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);
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,

```

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```

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();
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) {}

```

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```

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);
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>
↪ (::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance);
300 }
301 inline ::PROTOBUF_NAMESPACE_ID::UnknownFieldSet* mutable_unknown_fields() {
302   return _internal_metadata_.mutable_unknown_fields<::PROTOBUF_NAMESPACE_
↪ ID::UnknownFieldSet>();
303 }
304
305 static const ::PROTOBUF_NAMESPACE_ID::Descriptor* descriptor() {
306   return GetDescriptor();
307 }
308 static const ::PROTOBUF_NAMESPACE_ID::Descriptor* GetDescriptor() {
309   return default_instance().GetMetadata().descriptor;
310 }
311 static const ::PROTOBUF_NAMESPACE_ID::Reflection* GetReflection() {
312   return default_instance().GetMetadata().reflection;
313 }
314 static const Person& default_instance() {
315   return *internal_default_instance();
316 }
317 static inline const Person* internal_default_instance() {
318   return reinterpret_cast<const Person*>(
319     &_Person_default_instance_);

```

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```

320 }
321 static constexpr int kIndexInFileMessages =
322     1;
323
324 friend void swap(Person& a, Person& b) {
325     a.Swap(&b);
326 }
327 inline void Swap(Person* other) {
328     if (other == this) return;
329 #ifdef PROTOBUF_FORCE_COPY_IN_SWAP
330     if (GetOwningArena() != nullptr &&
331         GetOwningArena() == other->GetOwningArena()) {
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();

```

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```

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);
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) {

```

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```

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;
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:

```

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```

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

```

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```

523 AddressBook(const AddressBook& from);
524 AddressBook(AddressBook&& from) noexcept
525 : AddressBook() {
526     *this = ::std::move(from);
527 }
528
529 inline AddressBook& operator=(const AddressBook& from) {
530     CopyFrom(from);
531     return *this;
532 }
533 inline AddressBook& operator=(AddressBook&& from) noexcept {
534     if (this == &from) return *this;
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 =
    2;

```

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```

573 friend void swap(AddressBook& a, AddressBook& b) {
574     a.Swap(&b);
575 }
576 inline void Swap(AddressBook* other) {
577     if (other == this) return;
578 #ifdef PROTOBUF_FORCE_COPY_IN_SWAP
579     if (GetOwningArena() != nullptr &&
580         GetOwningArena() == other->GetOwningArena()) {
581     #else // PROTOBUF_FORCE_COPY_IN_SWAP
582     if (GetOwningArena() == other->GetOwningArena()) {
583 #endif // !PROTOBUF_FORCE_COPY_IN_SWAP
584         InternalSwap(other);
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_
606 ID::Message& from);
607 public:
608 PROTOBUF_ATTRIBUTE_REINITIALIZES void Clear() final;
609 bool IsInitialized() const final;
610
611 size_t ByteSizeLong() const final;
612 const char* _InternalParse(const char* ptr, ::PROTOBUF_NAMESPACE_
613 ID::internal::ParseContext* ctx) final;
614 uint8_t* _InternalSerialize(
615     uint8_t* target, ::PROTOBUF_NAMESPACE_ID::io::EpsCopyOutputStream* stream) const
616 final;
617 int GetCachedSize() const final { return _cached_size_.Get(); }
618
619 private:
620 void SharedCtor();
621 void SharedDtor();
622 void SetCachedSize(int size) const final;
623 void InternalSwap(AddressBook* other);

```

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```

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;
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 // =====

```

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```

674
675
676 // =====
677
678 #ifndef __GNUC__
679     #pragma GCC diagnostic push
680     #pragma GCC diagnostic ignored "-Wstrict-aliasing"
681 #endif // __GNUC__
682 // Person_PhoneNumber
683
684 // optional string number = 1;
685 inline bool Person_PhoneNumber::_internal_has_number() const {
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()) {

```

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```

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) {
738     if (number != nullptr) {
739         _has_bits_[0] |= 0x00000001u;
740     } else {
741         _has_bits_[0] &= ~0x00000001u;
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] & 0x00000002u) != 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] &= ~0x00000002u;
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] |= 0x00000002u;
774     type_ = value;
775 }
776 inline void Person_PhoneNumber::set_type(::tutorial::Person_PhoneType value) {
777     _internal_set_type(value);

```

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```

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 }
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] &= ~0x000000001u;
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] |= 0x000000001u;
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] |= 0x000000001u;
818     name_.Set(value, GetArenaForAllocation());
819 }
820 inline std::string* Person::_internal_mutable_name() {
821     _has_bits_[0] |= 0x000000001u;
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] &= ~0x000000001u;

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```

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] |= 0x000000001u;
841     } else {
842         _has_bits_[0] &= ~0x000000001u;
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] & 0x000000004u) != 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] &= ~0x000000004u;
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] |= 0x000000004u;
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;

```

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```

882 inline bool Person::_internal_has_email() const {
883     bool value = (_has_bits_[0] & 0x000000002u) != 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] &= ~0x000000002u;
892 }
893 inline const std::string& Person::email() const {
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 }

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```

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
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)

```

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```

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 {
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

```

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```

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

```

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(

```

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```

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 };
37 PROTOBUF_ATTRIBUTE_NO_DESTROY PROTOBUF_CONSTINIT PROTOBUF_ATTRIBUTE_INIT_PRIORITY1
38 ↪Person_PhoneNumberDefaultTypeInternal _Person_PhoneNumber_default_instance_;
39 PROTOBUF_CONSTEXPR Person::Person(
40     ::_pbi::ConstantInitialized)
41     : phones_()
42     , name_(&::_pbi::fixed_address_empty_string, ::_pbi::ConstantInitialized{})
43     , email_(&::_pbi::fixed_address_empty_string, ::_pbi::ConstantInitialized{})
44     , id_(0){}
45 struct PersonDefaultTypeInternal {
46     PROTOBUF_CONSTEXPR PersonDefaultTypeInternal()
47         : _instance(::_pbi::ConstantInitialized{}) {}
48     ~PersonDefaultTypeInternal() {}
49     union {
50         Person _instance;
51     };
52 };
53 PROTOBUF_ATTRIBUTE_NO_DESTROY PROTOBUF_CONSTINIT PROTOBUF_ATTRIBUTE_INIT_PRIORITY1
54 ↪PersonDefaultTypeInternal _Person_default_instance_;
55 PROTOBUF_CONSTEXPR AddressBook::AddressBook(
56     ::_pbi::ConstantInitialized)
57     : people_(){}
58 struct AddressBookDefaultTypeInternal {
59     PROTOBUF_CONSTEXPR AddressBookDefaultTypeInternal()
60         : _instance(::_pbi::ConstantInitialized{}) {}
61     ~AddressBookDefaultTypeInternal() {}
62     union {
63         AddressBook _instance;
64     };
65 };
66 PROTOBUF_ATTRIBUTE_NO_DESTROY PROTOBUF_CONSTINIT PROTOBUF_ATTRIBUTE_INIT_PRIORITY1
67 ↪AddressBookDefaultTypeInternal _AddressBook_default_instance_;
68 } // namespace tutorial
69 static ::_pb::Metadata file_level_metadata_hello_2eproto[3];
70 static const ::_pb::EnumDescriptor* file_level_enum_descriptors_hello_2eproto[1];
71 static constexpr ::_pb::ServiceDescriptor const** file_level_service_descriptors_hello_
72 ↪2eproto = nullptr;
73
74 const uint32_t TableStruct_hello_2eproto::offsets[] PROTOBUF_SECTION_VARIABLE(protodesc_
75 ↪cold) = {
76     PROTOBUF_FIELD_OFFSET(::tutorial::Person_PhoneNumber, _has_bits_),

```

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```

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_
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\022r\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"
    "\030\002 \001(\0162\032.tutorial.Person.PhoneType:\004HOME"

```

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```

121     "\"+\\n\\tPhoneType\\022\\n\\n\\006MOBILE\\020\\000\\022\\010\\n\\004HOME\\020\\001\\022\\010\\n\\004W"
122     "ORK\\020\\002\\"/\\n\\013AddressBook\\022 \\n\\006people\\030\\001 \\003\\0132\\020.t"
123     "utorial.Person"
124     ;
125     static ::_pbi::once_flag descriptor_table_hello_2eproto_once;
126     const ::_pbi::DescriptorTable descriptor_table_hello_2eproto = {
127         false, false, 294, descriptor_table_protodef_hello_2eproto,
128         "hello.proto",
129         &descriptor_table_hello_2eproto_once, nullptr, 0, 3,
130         schemas, file_default_instances, TableStruct_hello_2eproto::offsets,
131         file_level_metadata_hello_2eproto, file_level_enum_descriptors_hello_2eproto,
132         file_level_service_descriptors_hello_2eproto,
133     };
134     PROTOBUF_ATTRIBUTE_WEAK const ::_pbi::DescriptorTable* descriptor_table_hello_2eproto_
135     ↪getter() {
136         return &descriptor_table_hello_2eproto;
137     }
138     // Force running AddDescriptors() at dynamic initialization time.
139     PROTOBUF_ATTRIBUTE_INIT_PRIORITY2 static ::_pbi::AddDescriptorsRunner dynamic_init_dummy_
140     ↪hello_2eproto(&descriptor_table_hello_2eproto);
141     namespace tutorial {
142     const ::PROTOBUF_NAMESPACE_ID::EnumDescriptor* Person_PhoneType_descriptor() {
143         ::PROTOBUF_NAMESPACE_ID::internal::AssignDescriptors(&descriptor_table_hello_2eproto);
144         return file_level_enum_descriptors_hello_2eproto[0];
145     }
146     bool Person_PhoneType_IsValid(int value) {
147         switch (value) {
148             case 0:
149             case 1:
150             case 2:
151                 return true;
152             default:
153                 return false;
154         }
155     }
156     #if (__cplusplus < 201703) && (!defined(_MSC_VER) || (_MSC_VER >= 1900 && _MSC_VER <
157     ↪1912))
158     constexpr Person_PhoneType Person::MOBILE;
159     constexpr Person_PhoneType Person::HOME;
160     constexpr Person_PhoneType Person::WORK;
161     constexpr Person_PhoneType Person::PhoneType_MIN;
162     constexpr Person_PhoneType Person::PhoneType_MAX;
163     constexpr int Person::PhoneType_ARRAYSIZE;
164     #endif // (__cplusplus < 201703) && (!defined(_MSC_VER) || (_MSC_VER >= 1900 && _MSC_
165     ↪VER < 1912))
166     // =====
167     class Person_PhoneNumber::_Internal {
168     public:

```

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```

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) {
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);

```

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```

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;
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*
244     ↪ ctx) {
245     #define CHK_(x) if (PROTOBUF_PREDICT_FALSE(!(x))) goto failure
246     _Internal::HasBits has_bits{};
247     while (!ctx->Done(&ptr)) {
248         uint32_t tag;
249         ptr = ::_pbi::ReadTag(ptr, &tag);
250         switch (tag >> 3) {
251             // optional string number = 1;
252             case 1:
253                 if (PROTOBUF_PREDICT_TRUE(static_cast<uint8_t>(tag) == 10)) {
254                     auto str = _internal_mutable_number();
255                     ptr = ::_pbi::InlineGreedyStringParser(str, ptr, ctx);
256                     CHK_(ptr);
257                     #ifndef NDEBUG
258                     ::_pbi::VerifyUTF8(str, "tutorial.Person.PhoneNumber.number");
259                     #endif // !NDEBUG
260                 } else
261                     goto handle_unusual;
262                 continue;
263             // optional .tutorial.Person.PhoneType type = 2 [default = HOME];
264             case 2:
265                 if (PROTOBUF_PREDICT_TRUE(static_cast<uint8_t>(tag) == 16)) {
266                     uint64_t val = ::PROTOBUF_NAMESPACE_ID::internal::ReadVarint64(&ptr);
267                     CHK_(ptr);
268                     if (PROTOBUF_PREDICT_TRUE(::tutorial::Person_PhoneType_IsValid(val))) {
269                         _internal_set_type(static_cast<:tutorial::Person_PhoneType>(val));
270                     } else {

```

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```

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);
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);

```

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```

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>
326         ↳ (::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance), target, stream);
327 }
328 // @@protoc_insertion_point(serialize_to_array_end:tutorial.Person.PhoneNumber)
329 return target;
330 }
331
332 size_t Person_PhoneNumber::ByteSizeLong() const {
333     // @@protoc_insertion_point(message_byte_size_start:tutorial.Person.PhoneNumber)
334     size_t total_size = 0;
335
336     uint32_t cached_has_bits = 0;
337     // Prevent compiler warnings about cached_has_bits being unused
338     (void) cached_has_bits;
339
340     cached_has_bits = _has_bits_[0];
341     if (cached_has_bits & 0x000000003u) {
342         // optional string number = 1;
343         if (cached_has_bits & 0x000000001u) {
344             total_size += 1 +
345                 ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::StringSize(
346                     this->_internal_number());
347         }
348
349         // optional .tutorial.Person.PhoneType type = 2 [default = HOME];
350         if (cached_has_bits & 0x000000002u) {
351             total_size += 1 +
352                 ::_pbi::WireFormatLite::EnumSize(this->_internal_type());
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
366 void Person_PhoneNumber::MergeImpl(::PROTOBUF_NAMESPACE_ID::Message* to,
367     const ::PROTOBUF_NAMESPACE_ID::Message& from) {
368     static_cast<Person_PhoneNumber*>(to)->MergeFrom(
369         static_cast<const Person_PhoneNumber&>(from));
370 }

```

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```

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 & 0x000000003u) {
379     if (cached_has_bits & 0x000000001u) {
380       _internal_set_number(from._internal_number());
381     }
382     if (cached_has_bits & 0x000000002u) {
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

```

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```

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) {
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_
448 ↪ metadata_);
449     name_.InitDefault();
450     #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
451     name_.Set("", GetArenaForAllocation());
452     #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
453     if (from._internal_has_name()) {
454         name_.Set(from._internal_name(),
455                 GetArenaForAllocation());
456     }
457     email_.InitDefault();
458     #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING
459     email_.Set("", GetArenaForAllocation());
460     #endif // PROTOBUF_FORCE_COPY_DEFAULT_STRING
461     if (from._internal_has_email()) {
462         email_.Set(from._internal_email(),
463                 GetArenaForAllocation());
464     }
465     id_ = from.id_;
466     // @@protoc_insertion_point(copy_constructor:tutorial.Person)
467 }
468
469 inline void Person::SharedCtor() {
470     name_.InitDefault();
471     #ifdef PROTOBUF_FORCE_COPY_DEFAULT_STRING

```

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```

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>()) {
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 & 0x00000003u) {
508         if (cached_has_bits & 0x00000001u) {
509             name_.ClearNonDefaultToEmpty();
510         }
511         if (cached_has_bits & 0x00000002u) {
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

```

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```

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 // !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:

```

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```

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_
↪ ID::UnknownFieldSet>(),
585         ptr, ctx);
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,

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```

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
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 & 0x00000007u) {
664         // optional string name = 1;
665         if (cached_has_bits & 0x00000001u) {
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 & 0x00000002u) {
673             total_size += 1 +
674                 ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::StringSize(
675                     this->_internal_email());
676         }
677     }
678 }

```

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```

676 // optional int32 id = 2;
677 if (cached_has_bits & 0x00000004u) {
678     total_size += ::_pbi::WireFormatLite::Int32SizePlusOne(this->_internal_id());
679 }
680 }
681 }
682 return MaybeComputeUnknownFieldsSize(total_size, &_cached_size_);
683 }
684 }
685
686 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData Person::_class_data_ = {
687     ::PROTOBUF_NAMESPACE_ID::Message::CopyWithSizeCheck,
688     Person::MergeImpl
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 void Person::MergeFrom(const Person& from) {
699 // @@protoc_insertion_point(class_specific_merge_from_start:tutorial.Person)
700     GOOGLE_DCHECK_NE(&from, this);
701     uint32_t cached_has_bits = 0;
702     (void) cached_has_bits;
703
704     phones_.MergeFrom(from.phones_);
705     cached_has_bits = from._has_bits_[0];
706     if (cached_has_bits & 0x00000007u) {
707         if (cached_has_bits & 0x00000001u) {
708             _internal_set_name(from._internal_name());
709         }
710         if (cached_has_bits & 0x00000002u) {
711             _internal_set_email(from._internal_email());
712         }
713         if (cached_has_bits & 0x00000004u) {
714             id_ = from.id_;
715         }
716         _has_bits_[0] |= cached_has_bits;
717     }
718     _internal_metadata_.MergeFrom<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>(from._internal_
↪ metadata_);
719 }
720
721 void Person::CopyFrom(const Person& from) {
722 // @@protoc_insertion_point(class_specific_copy_from_start:tutorial.Person)
723     if (&from == this) return;
724     Clear();
725 }

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```

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]);
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
771 AddressBook::AddressBook(const AddressBook& from)
772     : ::PROTOBUF_NAMESPACE_ID::Message(),
773     people_(from.people_) {
774     _internal_metadata_.MergeFrom<::PROTOBUF_NAMESPACE_ID::UnknownFieldSet>(from._internal_
775     metadata_);
776     // @@protoc_insertion_point(copy_constructor:tutorial.AddressBook)
777 }

```

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```

777 inline void AddressBook::SharedCtor() {
778 }
779
780 AddressBook::~AddressBook() {
781     // @@protoc_insertion_point(destructor:tutorial.AddressBook)
782     if (auto *arena = _internal_metadata_.DeleteReturnArena<:PROTOBUF_NAMESPACE_
↪ ID::UnknownFieldSet>()) {
783         (void)arena;
784         return;
785     }
786     SharedDtor();
787 }
788
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;

```

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```

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_
↪ ID::UnknownFieldSet>(),
838         ptr, ctx);
839     CHK_(ptr != nullptr);
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>
↪ (::PROTOBUF_NAMESPACE_ID::UnknownFieldSet::default_instance), target, stream);
866     }
867     // @@protoc_insertion_point(serialize_to_array_end:tutorial.AddressBook)
868     return target;
869 }
870
871 size_t AddressBook::ByteSizeLong() const {
872     // @@protoc_insertion_point(message_byte_size_start:tutorial.AddressBook)
873     size_t total_size = 0;
874
875     uint32_t cached_has_bits = 0;
876     // Prevent compiler warnings about cached_has_bits being unused
877     (void) cached_has_bits;

```

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```

878
879 // repeated .tutorial.Person people = 1;
880 total_size += 1UL * this->_internal_people_size();
881 for (const auto& msg : this->people_) {
882     total_size +=
883         ::PROTOBUF_NAMESPACE_ID::internal::WireFormatLite::MessageSize(msg);
884 }
885
886 return MaybeComputeUnknownFieldsSize(total_size, &_cached_size_);
887 }
888
889 const ::PROTOBUF_NAMESPACE_ID::Message::ClassData AddressBook::_class_data_ = {
890     ::PROTOBUF_NAMESPACE_ID::Message::CopyWithSizeCheck,
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 }

```

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```
928
929 ::PROTOBUF_NAMESPACE_ID::Metadata AddressBook::GetMetadata() const {
930     return ::_pbi::AssignDescriptors(
931         &descriptor_table_hello_2eproto_getter, &descriptor_table_hello_2eproto_once,
932         file_level_metadata_hello_2eproto[2]);
933 }
934
935 // @@protoc_insertion_point(namespace_scope)
936 } // namespace tutorial
937 PROTOBUF_NAMESPACE_OPEN
938 template<> PROTOBUF_NOINLINE ::tutorial::Person_PhoneNumber*
939 Arena::CreateMaybeMessage< ::tutorial::Person_PhoneNumber >(Arena* arena) {
940     return Arena::CreateMessageInternal< ::tutorial::Person_PhoneNumber >(arena);
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>
```