Exploring JIT compilation in TorchDynamo

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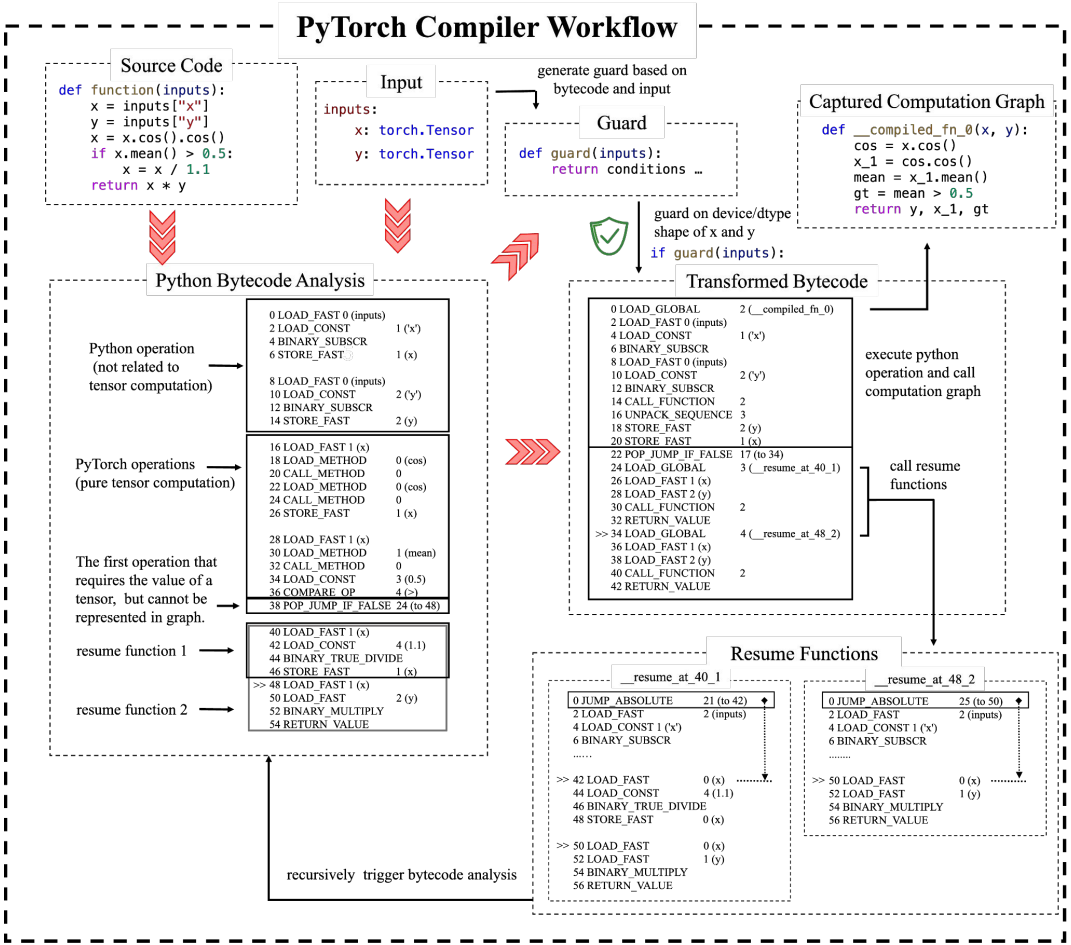
How to make my PyTorch models faster?

torch.compile

- JIT
- Operates on the Python Bytecode level
- Supports various target architectures through different backends

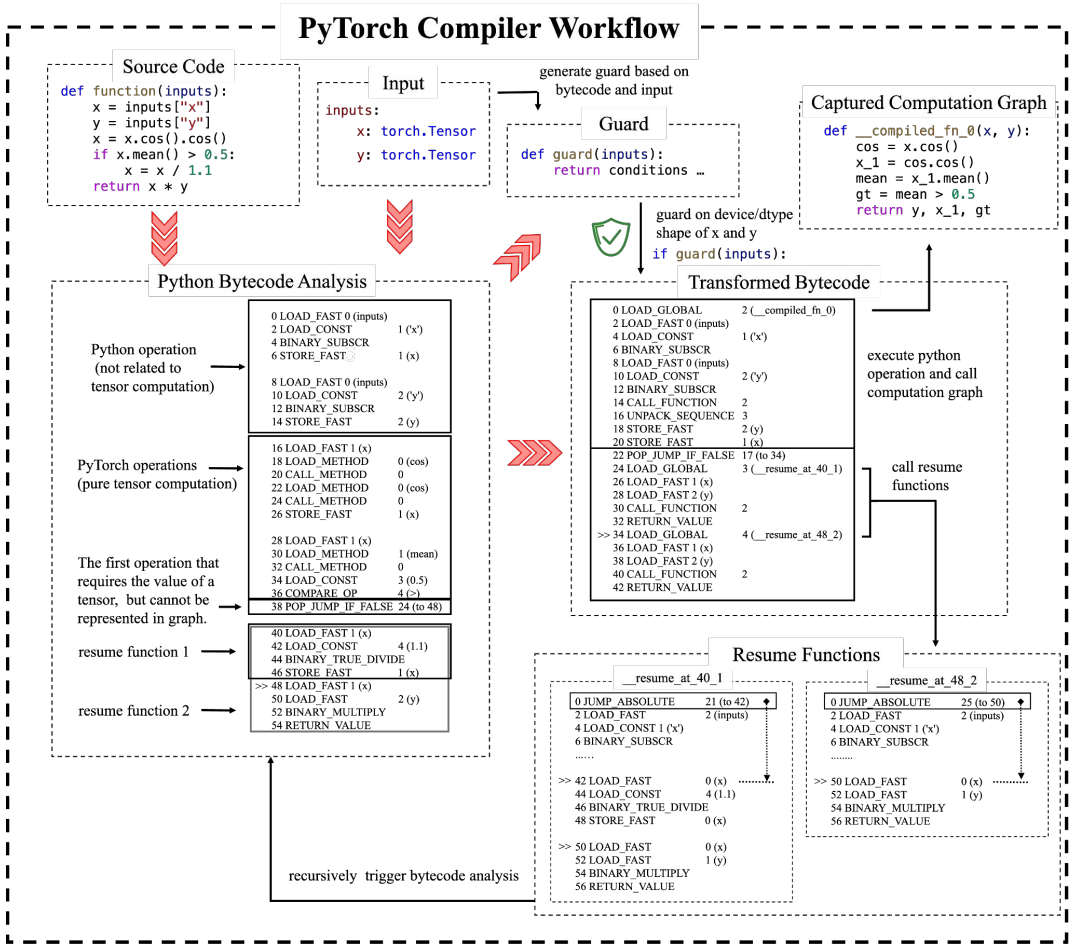


https://depyf.readthedocs.io/en/latest/walk_through.html

torch.compile

3 elements:

- TorchDynamo - tracer
- AoT Autograd - another tracer
- Inductor - compiler backend



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torch.compile

```python
# ex.py
import torch

@torch.compile
def lerp(x, y, w):
    return w * x + (1 - w) * y

x = torch.randn(200)
y = torch.randn(200)
w = torch.rand(200)
result = lerp(x, y, w)
```

```cpp
// Simplified output of running
// TORCH_LOGS=output_code python ex.py
void lerp(const float* w_ptr,
          const float* x_ptr,
          const float* y_ptr,
          float* out_ptr0) {
    for(long x0=0; x0<200; x0+=1L) {
        auto tmp0 = w_ptr[x0];
        auto tmp1 = x_ptr[x0];
        auto tmp5 = y_ptr[x0];
        auto tmp2 = tmp0 * tmp1;
        auto tmp3 = c10::convert<double>(1.0);
        auto tmp4 = tmp3 - tmp0;
        auto tmp6 = tmp4 * tmp5;
        auto tmp7 = tmp2 + tmp6;
        out_ptr0[x0] = tmp7
    }
}
```

https://www.youtube.com/watch?v=Z3dL2D2BEHE

Modes of Execution in Pytorch

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Eager mode

- Operations are executed immediately when they are encountered
- Intuitive and flexible

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Graph mode

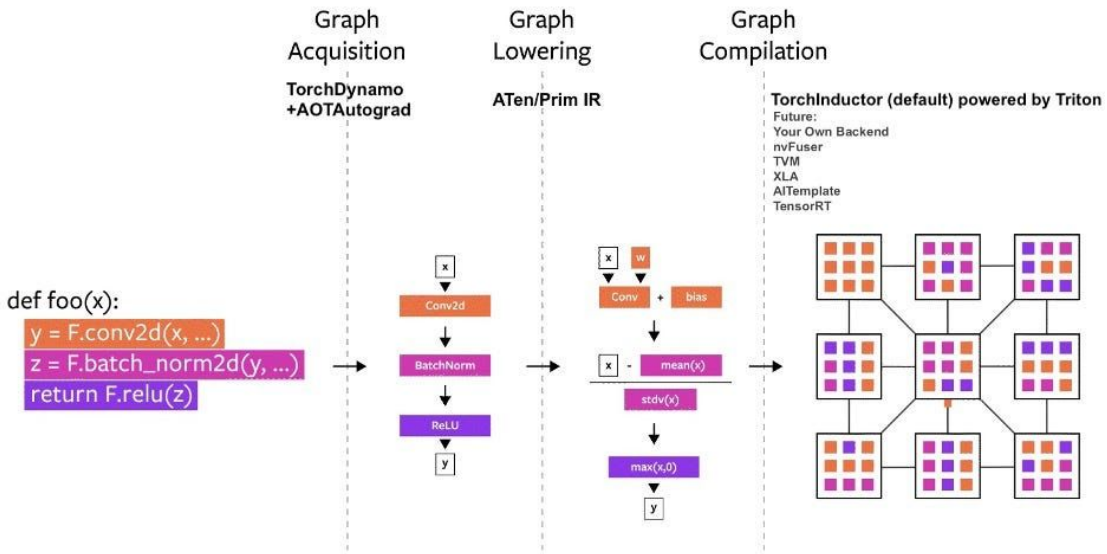
- Delays execution after the forward pass is performed
- Creates a computational graph from operations, allowing for optimisations

Modes of Execution in Pytorch

Eager mode

```
def f1(x, y):
    if x.sum() < 0:
        return -y
    return y
```

Graph mode



https://pytorch.org/get-started/pytorch-2.0/

How to Capture a Computation Graph in PyTorch?

Eager mode

- Graph created on the fly!
- Super helpful for debugging

A graph is created on the fly


```
W_h = torch.randn(20, 20, requires_grad=True)
W_x = torch.randn(20, 10, requires_grad=True)
x = torch.randn(1, 10)
prev_h = torch.randn(1, 20)
```

the nuances of pytorch graph capture

https://pytorch.org/tutorials/beginner/Intro_to_TorchScript_tutorial.htm

How to Capture a Computation Graph in PyTorch?

Graph mode

```
def f1(x, y):
    x = torch.sin(x)
    x = torch.matmul(x, y)
    if x.sum() < 0:
        return -y
    return y
```

How to Capture a Computation Graph in PyTorch?

Graph mode

- ???

```
def f1(x, y):
    x = torch.sin(x)
    x = torch.matmul(x, y)
    if x.sum() < 0:
        return -y
    return y
```

How to Capture a Computation Graph in PyTorch?

```python
@torch.compile
def mse(x, y):
    z = (x - y) ** 2
    return z.sum()

x = torch.randn(200)
y = torch.randn(200)
mse(x, y)
```

```python
def forward(l_x_: torch.Tensor,
            l_y_: torch.Tensor):
    # File: ex.py:30, code: z = (x - y) ** 2
    sub = l_x_ - l_y_
    z = sub ** 2
    # File: ex.py:31, code: return z.sum()
    sum_1 = z.sum()
    return (sum_1,)
```

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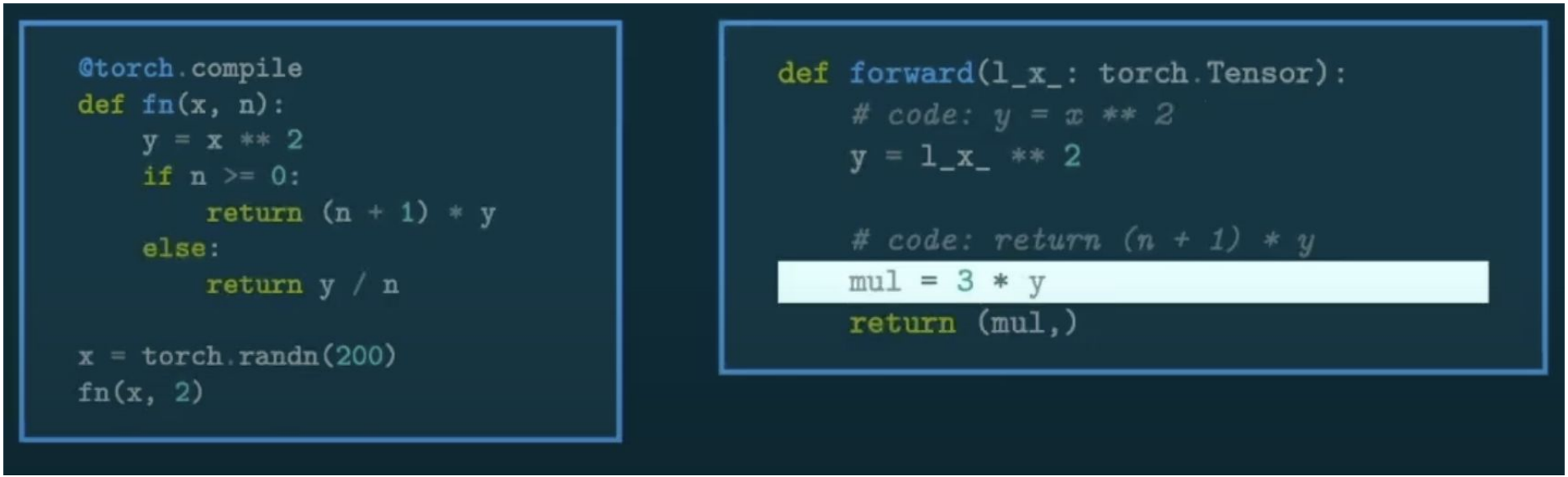
How to Capture a Computation Graph in PyTorch?



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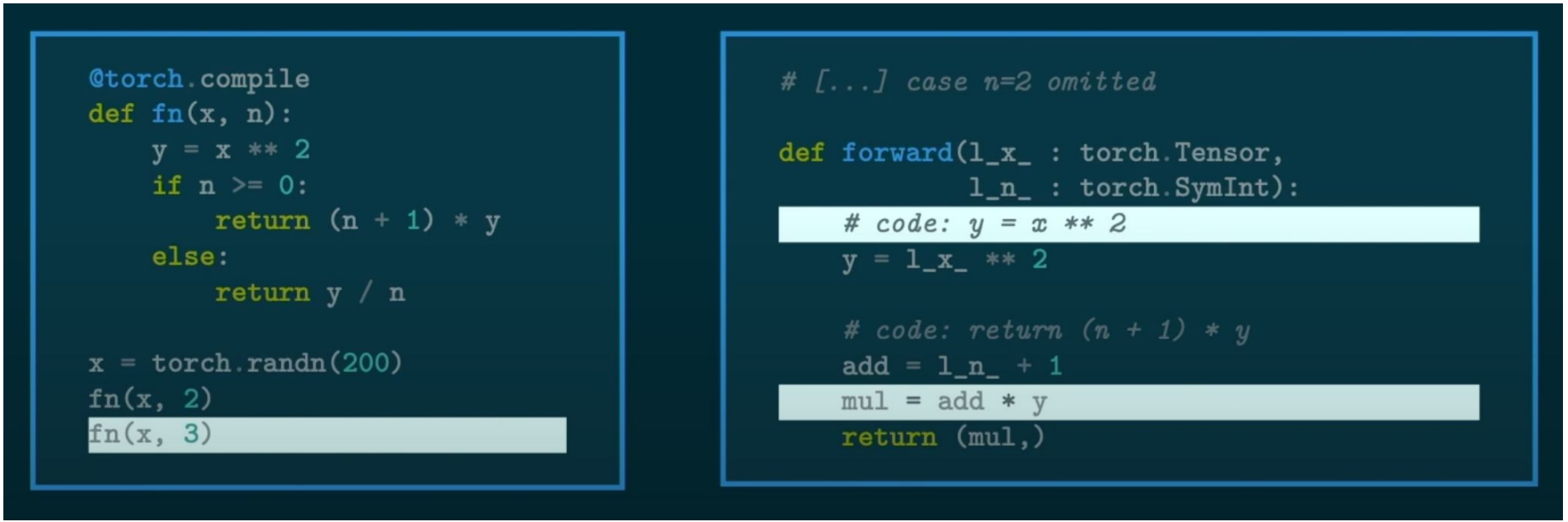
How to Capture a Computation Graph in PyTorch?



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How to Capture a Computation Graph in PyTorch?

```python
@torch.compile
def fn(x, n):
    y = x ** 2
    if n >= 0:
        return (n + 1) * y
    else:
        return y / n

x = torch.randn(200)
fn(x, 2)
fn(x, 3)
fn(x, 6)   # can use n >= 0
fn(x, -3) # retrace!
```

```python
# [...] case n==2 omitted
# [...] case n>=0 omitted

def forward(l_x_ : torch.Tensor,
            l_n_ : torch.SymInt):
    # code: y = x ** 2
    y = l_x_ ** 2

    # code: return y / n
    truediv = y / l_n_
    return (truediv,)
```

https://www.youtube.com/watch?v=Z3dL2D2BEHE

How to Capture a Computation Graph in PyTorch?

Graph mode (static graphs)

- `torch.jit.script`
- `torch.jit.trace`

- Require changes to the code

```
def f1(x, y):
    x = torch.sin(x)
    x = torch.matmul(x, y)
    if x.sum() < 0:
        return -y
    return y
```

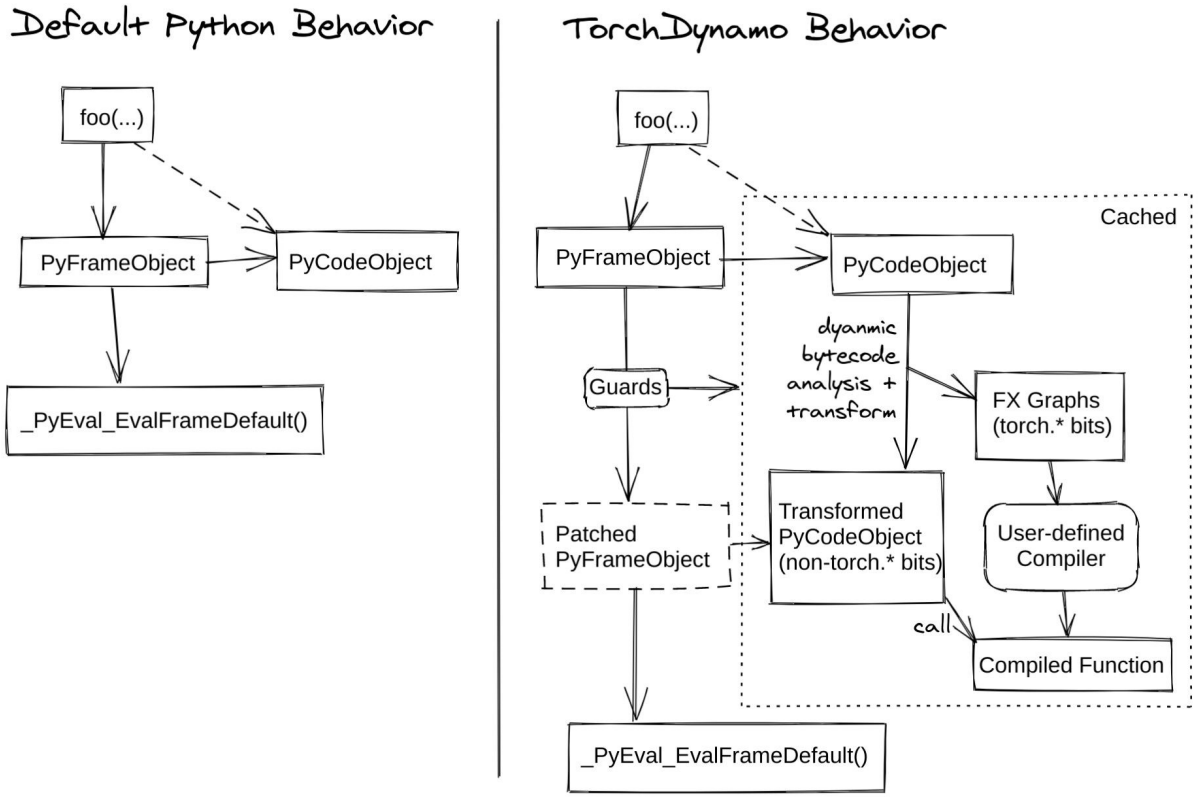
How to Capture a Computation Graph in PyTorch?

Graph mode (TorchDynamo)

- Uses CPython frame evaluation API
- Splits code into graph and non-graph parts
- Optimises the graph

```
def f1(x, y):
    x = torch.sin(x)
    x = torch.matmul(x, y)
    if x.sum() < 0:
        return -y
    return y
```

TorchDynamo



https://pytorch.org/docs/stable/torch.compiler_dynamo_overview.html

Question

How different neural architectures are represented in FX graph and what optimisations they allow for?

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How different neural architectures are represented in FX graph and what optimisations they allow for?

- Explore the graph capture and optimisation of NN components (e.g. FFNN, attention), including dynamic model shapes with TorchDynamo and TorchInductor
- Consider custom hardware-specific optimisations (e.g. operation fusion, memory layout)
- Evaluate various configurations of the `torch.compile()` framework on real-world use-cases

Thank you!