Module 0.1 - Fundamentals

Module 0.1

Fundamentals

Today's Class

- Intro: Module 0
- Development Setup
- Property Testing
- Functional Python

The Guidebook

MiniTorch

Full description of the material

Module 0: Fundamentals

Learning Goals:

- Setup
- Testing
- Modules
- Visualization
- No ML yet! We'll get to it.

Code Setup: Interactive

GitHub

- http://github.com/minitorch/Module-0

Graduating to Code

Why not notebooks?

- Style
- Version Control
- Testing

Base Repo Template

- Each repo starts with a template
- https://github.com/minitorch/Module-0

Tour of Repo

- `minitorch/`
- `tests/`
- `project/`

Recommendations

- Development Setup
- Github Tutorials
- Speed of Debugging

VS Code / Cursor

- Popular choice for the class
- Test
- Debugging

Contributing Guidelines

Contributing

Torch Contrib

- Style, guidelines, typing, etc.

Configuations

- pyproject.toml

Precommit

Command to run before commit.

```
>>> pre-commit run --all
```

Consistent Styling

Standardized formatting

```
>>> ruff
```

Linting

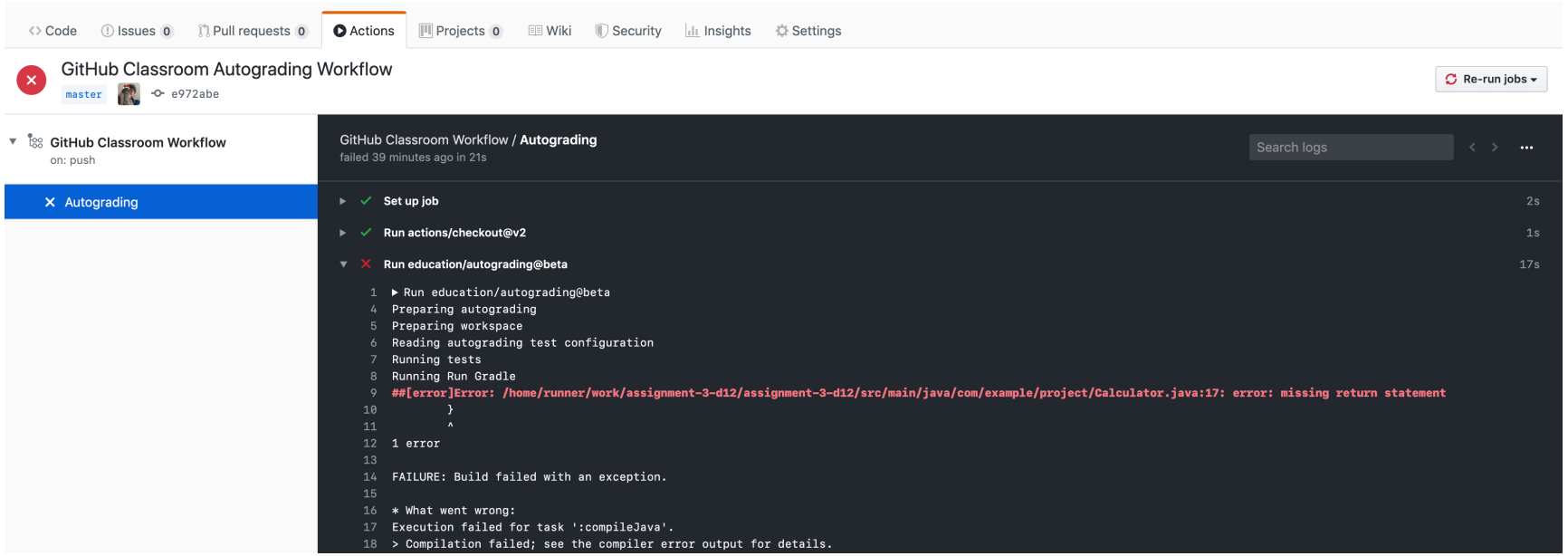
Ruff will also do linting for you now

```
>>> ruff check
```

Continuous Integration

Runs behind the scenes on every commit.

Torch CI



Documentation

Doc style - Google

```
def index(ls, i):
    """
    List indexing.

    Args:
      ls: A list of any type.
      i: An index into the list

    Returns:
       Value at ls[i].
    """
    ...
```

Documentation

Simple Docs

```
def mul(x, y):
    "Multiply `x` by `y`"
    ...
```

AI Tools

- AI for understanding the code base
- AI for documentation / typing
- AI for code generation

Type Checks

Modern Python support static type checks

```
>>> pyright
```

```
def mul(x: float, y: float) -> float: ...
```

Type Checks

Compound types

```
from typing import Iterable


def negList(ls: Iterable[float]) -> Iterable[float]: ...
```

Testing

PyTorch Testing

PyTorch Tests

Running Tests

Run tests

```
>>> pytest
```

Or per task

```
>>> pytest -m task0_1
```

PyTest

- Finds files that begin with `test`
- Finds functions that begin with `test`
- Select based on filters

Gotchas

- Test output is verbose
- Read tests

Helpful Filters

Specific task

```
>>> pytest -m task0_1
```

Specific test

```
>>> pytest -k test_sum
```

How do unit tests work?

- Tries to run code
- If there is a False assert it fails
- Only prints if test fails!
- `assert` and `assert_close`

Module 0 Functions

```
def relu(x):
    """
    f(x) = x if x is greater than 0, else 0
    """
    ...
```

Mathematical Testing

- How do we know that it works?

Standard Unit Test

- Test for values with given inputs
- PyTest succeeds if no assertions are called

```
def test_relu():
    assert operators.relu(10.0) == 10.0
    assert operators.relu(-10.0) == 0.0
```

Ideal: Property Test

Test that all values satisfy property

```
def test_relu():
    for a in range(0, 1e9):
        assert operators.relu(a) == a

    for a in range(-1e9, 0):
        assert operators.relu(a) == 0.0
```

QuickCheck / Hypothesis

- https://en.wikipedia.org/wiki/QuickCheck
- https://hypothesis.readthedocs.io/en/latest/

Compromise: Randomized Property Test

Test that sampled values satisfy property.

```python
from hypothesis import example, given
from hypothesis.strategies import floats


@given(floats())
@example(1.0)
def test_relu(a: float):
    value = relu(a)
    if a >= 0:
        assert value == a
    else:
        assert value == 0.0
```

Custom Generators

- Can provide your own randomized generators
- Future assignments will utilize this feature.

Functional Python

Functional Programming

- Style of programming where functions can be passed and used like other objects.
- One of several programming styles supported in Python.
- Good paradigm for mathematical programming

Function Type

```python
from typing import Callable


def add(a: float, b: float) -> float:
    return a + b


def mul(a: float, b: float) -> float:
    return a * b


v: Callable[[float, float], float] = add
```

Functions as Arguments

```
def combine3(
    fn: Callable[[float, float], float], a: float, b: float, c: float
) -> float:
    return fn(fn(a, b), c)


print(combine3(add, 1, 3, 5))
print(combine3(mul, 1, 3, 5))
```

```
9
15
```

Functional Python

Functions as Returns

```
def combine3(
    fn: Callable[[float, float], float],
) -> Callable[[float, float, float], float]:
    def new_fn(a: float, b: float, c: float) -> float:
        return fn(fn(a, b), c)

    return new_fn
```

```
add3: Callable[[float, float, float], float] = combine3(add)
mul3: Callable[[float, float, float], float] = combine3(mul)

print(add3(1, 3, 5))
```

```
9
```

```
type(add3)
```

```
function
```

Higher-order Filter

Extended example

```
def filter(fn: Callable[[float], bool]) -> Callable[[Iterable[float]], Iterable[fl
    def apply(ls: Iterable[float]):
        ret = []
        for x in ls:
            if fn(x):
                ret.append(x)
        return ret

    return apply
```

Higher-order Filter

Extended example

```
def more_than_4(x: float) -> bool:
    return x > 4


filter_for_more_than_4: Callable[[Iterable[float]], Iterable[float]] = filter(
    more_than_4
)
filter_for_more_than_4([1, 10, 3, 5])
```

```
[10, 5]
```

Functional Python

Rules of Thumbs:

- When in doubt, write out defs
- Document the arguments that functions take and send
- Write tests in for loops to sanity check

Q&A