



# 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

- Popular choice for the class
- Test
- Debugging





# Contributing Guidelines



# Contributing

## Torch Contrib

- Style, guidelines, typing, etc.



# Precommit

Command to run before commit.

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



# Consistent Styling

## Standardized formatting

```
>>> black minitorch/ tests/ project/
```





# Linting

Checks for any style or documentation errors

```
>>> flake8 minitorch/ tests/ project/
```



# Continuous Integration

Runs behind the scenes on every commit.

## Torch CI

Code Issues 0 Pull requests 0 Actions Projects 0 Wiki Security Insights Settings

GitHub Classroom Autograding Workflow Re-run jobs

master e972abe

GitHub Classroom Workflow on: push

Autograding

GitHub Classroom Workflow / Autograding failed 39 minutes ago in 21s

Search logs

- Set up job 2s
- Run actions/checkout@v2 1s
- Run education/autograding@beta 17s
  - Run education/autograding@beta
    - Preparing autograding
    - Preparing workspace
    - Reading autograding test configuration
    - Running tests
    - Running Run Gradle
    - ##[error]Error: /home/runner/work/assignment-3-d12/assignment-3-d12/src/main/java/com/example/project/Calculator.java:17: error: missing return statement**
    - 1 error
    - FAILURE: Build failed with an exception.
    - \* What went wrong:  
Execution failed for task ':compileJava'.
    - > Compilation failed; see the compiler error output for details.



# 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].  
    """  
    ...
```



# Type Checks

Modern Python support static type checks

```
>>> mypy
```

```
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.

```
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

```
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))
```

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# 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))
```

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```
type(add3)
```

function





# Higher-order Filter

## Extended example

```
def filter(fn: Callable[[float], bool]) -> Callable[[Iterable[float]], Iterable[float]]:
    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



