Automating Awkward Array Testing

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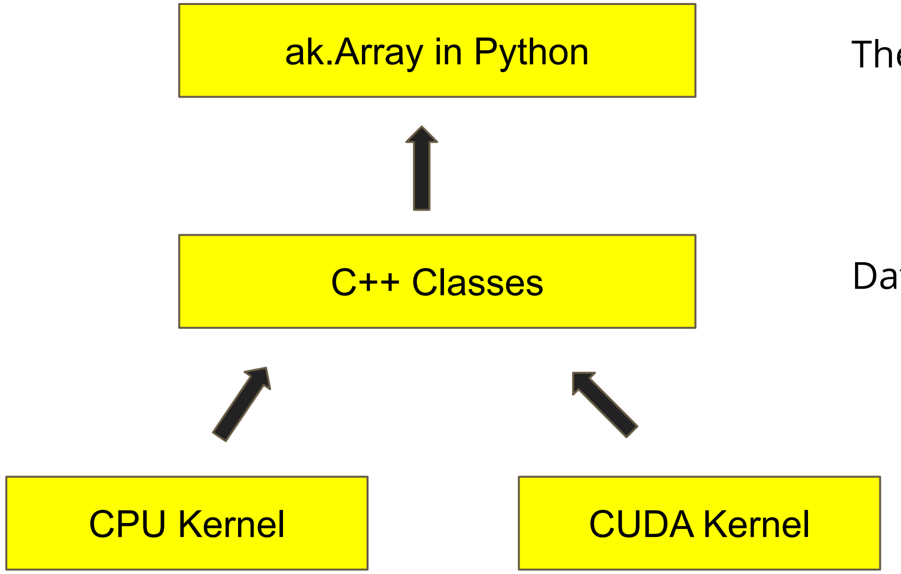
The Different Layers in Awkward Array



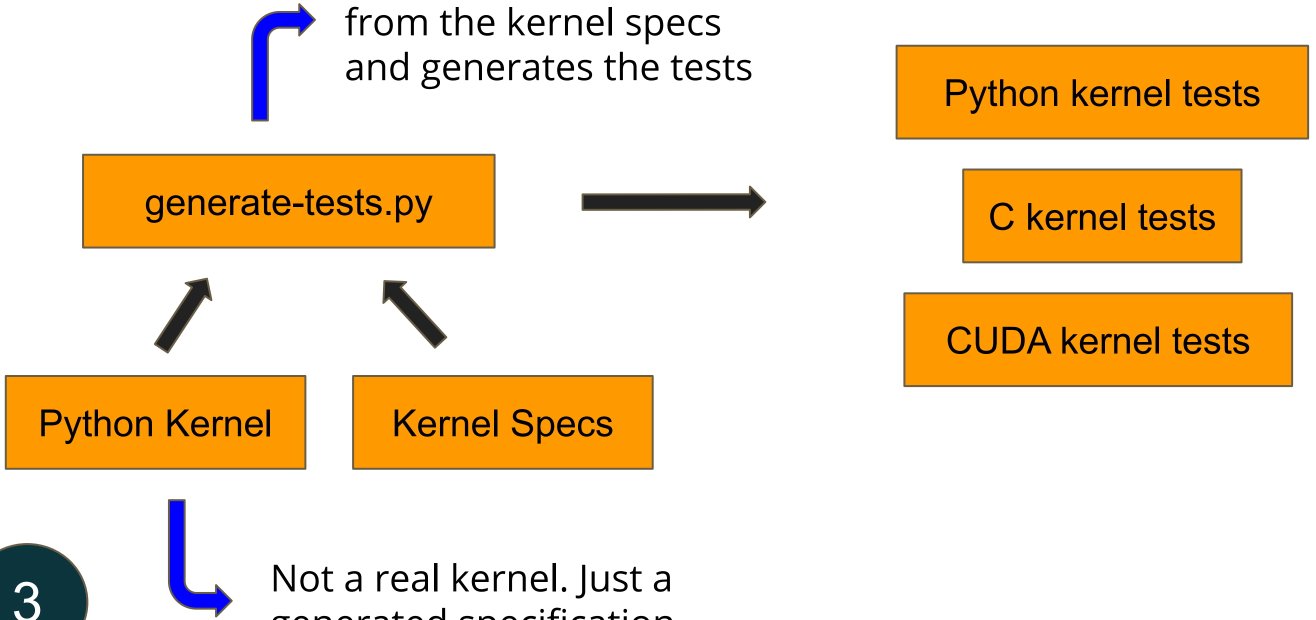
The one we interact with

Data Navigation

Operates on CPU Pointers

Operates on GPU Pointers

The Current Testing Infrastructure

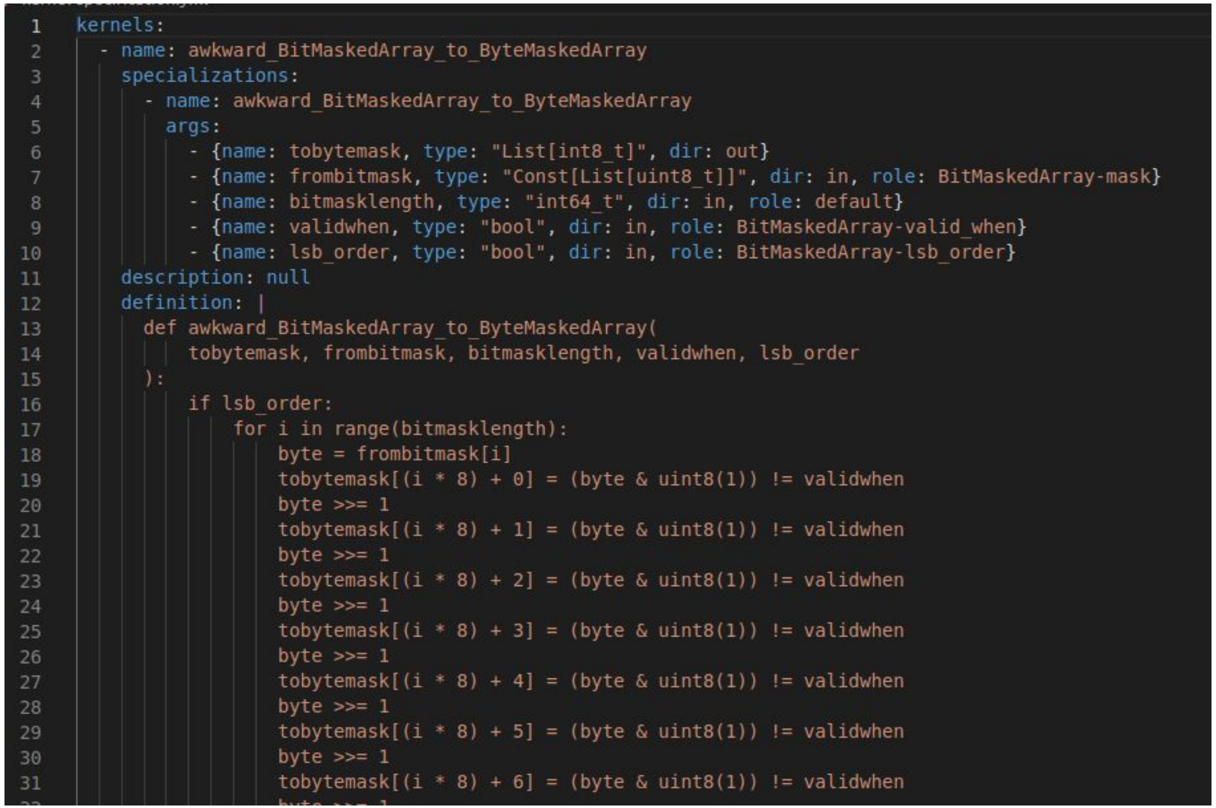


Creates a python kernel from the kernel specs and generates the tests

Auto generated tests

Not a real kernel. Just a generated specification.

The Kernel Specification

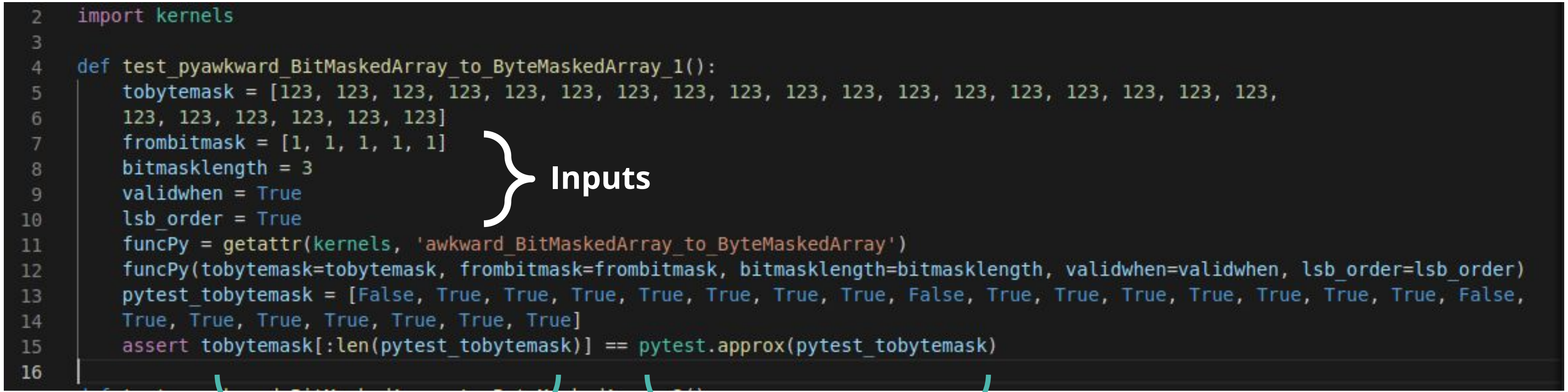


```
kernels:
  - name: awkward_BitMaskedArray_to_ByteMaskedArray
    specializations:
      - name: awkward_BitMaskedArray_to_ByteMaskedArray
        args:
          - {name: tobytemask, type: "List[int8_t]", dir: out}
          - {name: frombitmask, type: "Const[List[uint8_t]]", dir: in, role: BitMaskedArray-mask}
          - {name: bitmasklength, type: "int64_t", dir: in, role: default}
          - {name: validwhen, type: "bool", dir: in, role: BitMaskedArray-valid_when}
          - {name: lsb_order, type: "bool", dir: in, role: BitMaskedArray-lsb_order}
    description: null
    definition: |
      def awkward_BitMaskedArray_to_ByteMaskedArray(
          tobytemask, frombitmask, bitmasklength, validwhen, lsb_order
      ):
          if lsb_order:
              for i in range(bitmasklength):
                  byte = frombitmask[i]
                  tobytemask[(i * 8) + 0] = (byte & uint8(1)) != validwhen
                  byte >>= 1
                  tobytemask[(i * 8) + 1] = (byte & uint8(1)) != validwhen
                  byte >>= 1
                  tobytemask[(i * 8) + 2] = (byte & uint8(1)) != validwhen
                  byte >>= 1
                  tobytemask[(i * 8) + 3] = (byte & uint8(1)) != validwhen
                  byte >>= 1
                  tobytemask[(i * 8) + 4] = (byte & uint8(1)) != validwhen
                  byte >>= 1
                  tobytemask[(i * 8) + 5] = (byte & uint8(1)) != validwhen
                  byte >>= 1
                  tobytemask[(i * 8) + 6] = (byte & uint8(1)) != validwhen
```

Arguments

Function Definition

A Python Kernel Test



```python
import kernels

def test_pyawkward_BitMaskedArray_to_ByteMaskedArray_1():
    tobytemask = [123, 123, 123, 123, 123, 123, 123, 123, 123, 123, 123, 123, 123, 123, 123, 123, 123, 123,
    123, 123, 123, 123, 123, 123]
    frombitmask = [1, 1, 1, 1, 1]
    bitmasklength = 3
    validwhen = True
    lsb_order = True
    funcPy = getattr(kernels, 'awkward_BitMaskedArray_to_ByteMaskedArray')
    funcPy(tobytemask=tobytemask, frombitmask=frombitmask, bitmasklength=bitmasklength, validwhen=validwhen, lsb_order=lsb_order)
    pytest_tobytemask = [False, True, True, True, True, True, True, True, False, True, True, True, True, True, True, True, False,
    True, True, True, True, True, True, True]
    assert tobytemask[:len(pytest_tobytemask)] == pytest.approx(pytest_tobytemask)
```

Inputs

Result got from kernel

Result we are expecting

Does it cover all of the test cases?

NO

What are some of the loopholes here?

- Not too many specific test cases
- Not testing for specific errors
- The roles of the arguments are not well defined

What is a good solution to fill up the gap?

Property based Testing

What is property based testing?

A type of test in which we define the properties of the input and the output that we are expecting

What is the advantage of having property based tests?

- More hard coded input datas to test with
- Test a larger section of the codebase
- Very little code
- More efficient
- Flexible

Hypothesis Library

- *A boon to property based testing*

- Various strategies to get constraints based data
- Get a more elaborative test result
- Regenerate failing test inputs
- Shrinking

And much more..

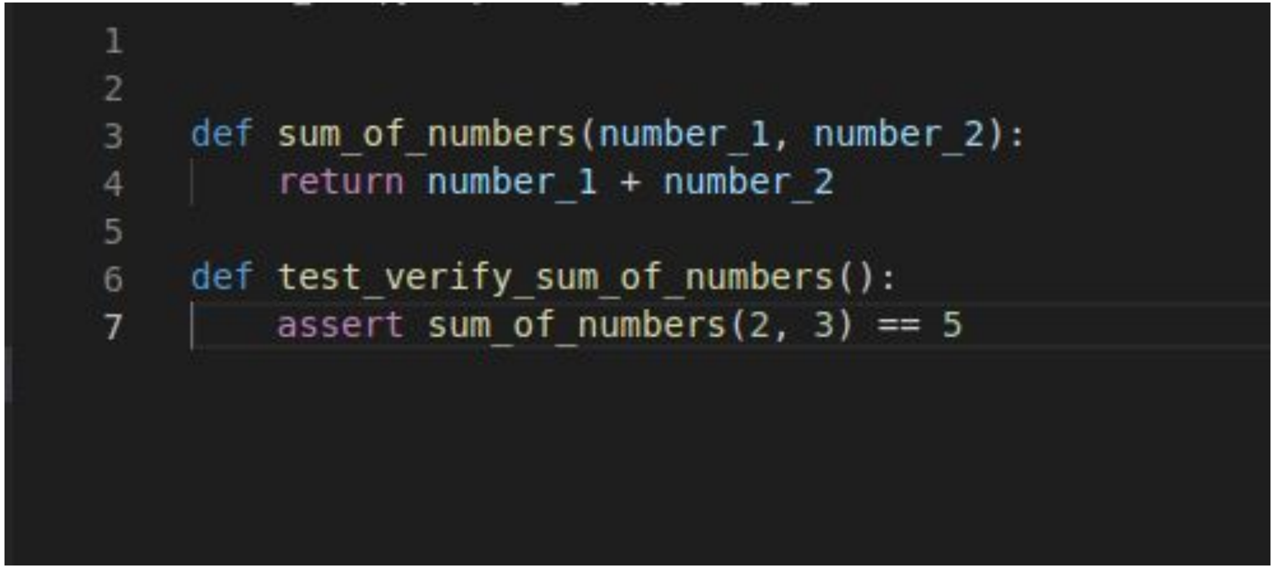
How a unit test runs

$$\begin{tikzcd}\text{Input Data} \arrow[r] & \text{Perform an operation} \arrow[r] & \text{Assert the result}\end{tikzcd}$$

How a tests written using hypothesis runs

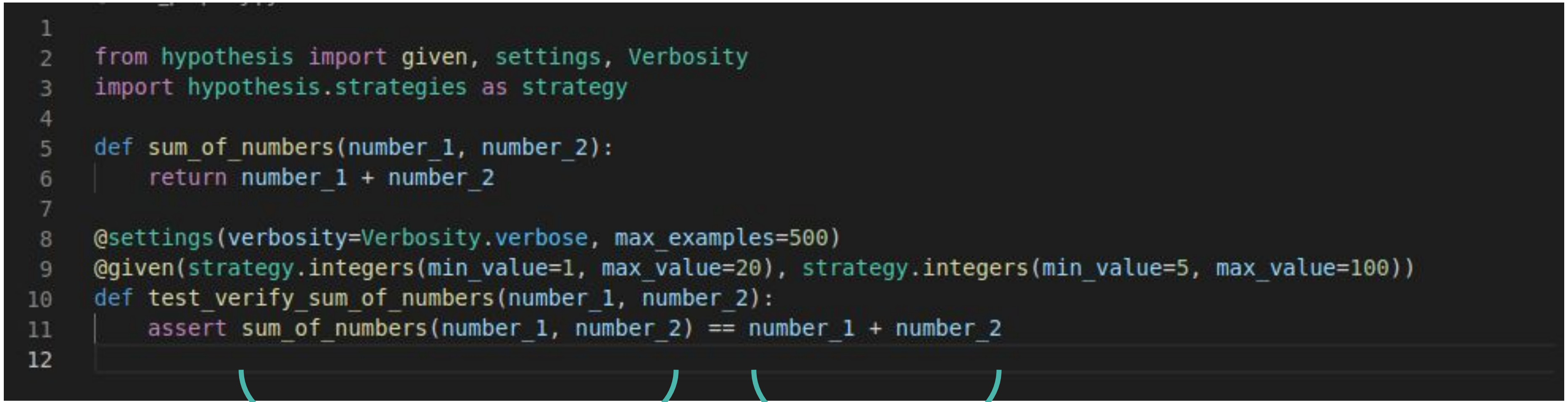
$$\begin{tikzcd}\text{Input Data based on some constraints} \arrow[r] & \text{Perform an operation} \arrow[r] & \text{Assert the result}\end{tikzcd}$$

A sample unit test



```python


def sum_of_numbers(number_1, number_2):
    return number_1 + number_2

def test_verify_sum_of_numbers():
    assert sum_of_numbers(2, 3) == 5
```

A similar property based test



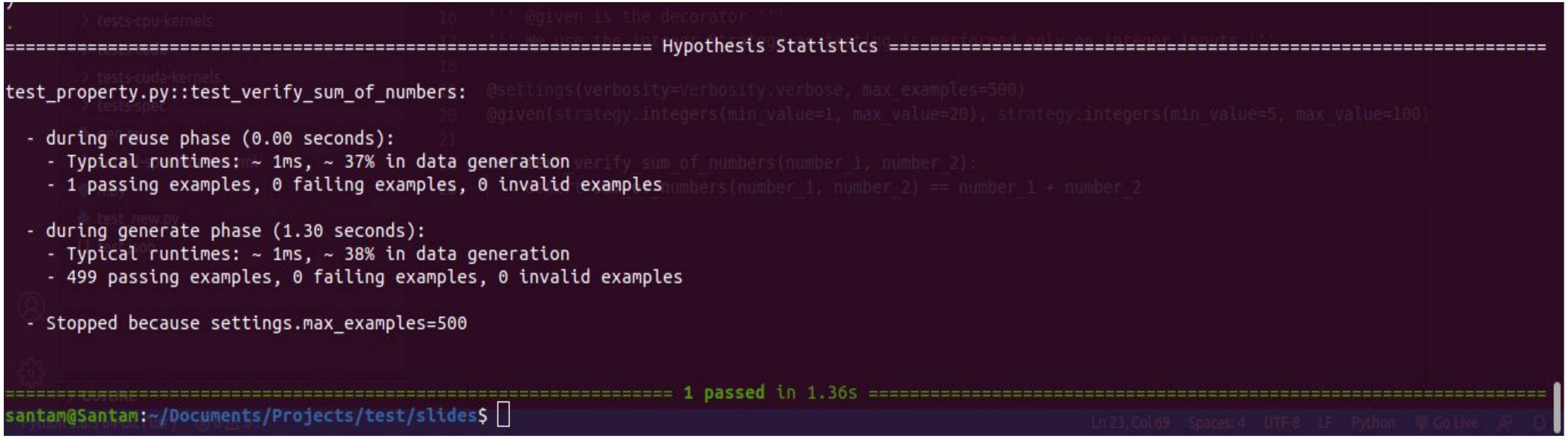
```python

from hypothesis import given, settings, Verbosity
import hypothesis.strategies as strategy

def sum_of_numbers(number_1, number_2):
    return number_1 + number_2

@settings(verbosity=Verbosity.verbose, max_examples=500)
@given(strategy.integers(min_value=1, max_value=20), strategy.integers(min_value=5, max_value=100))
def test_verify_sum_of_numbers(number_1, number_2):
    assert sum_of_numbers(number_1, number_2) == number_1 + number_2

```

The CPU Kernel Function will come here

The Python Kernel Function will come here

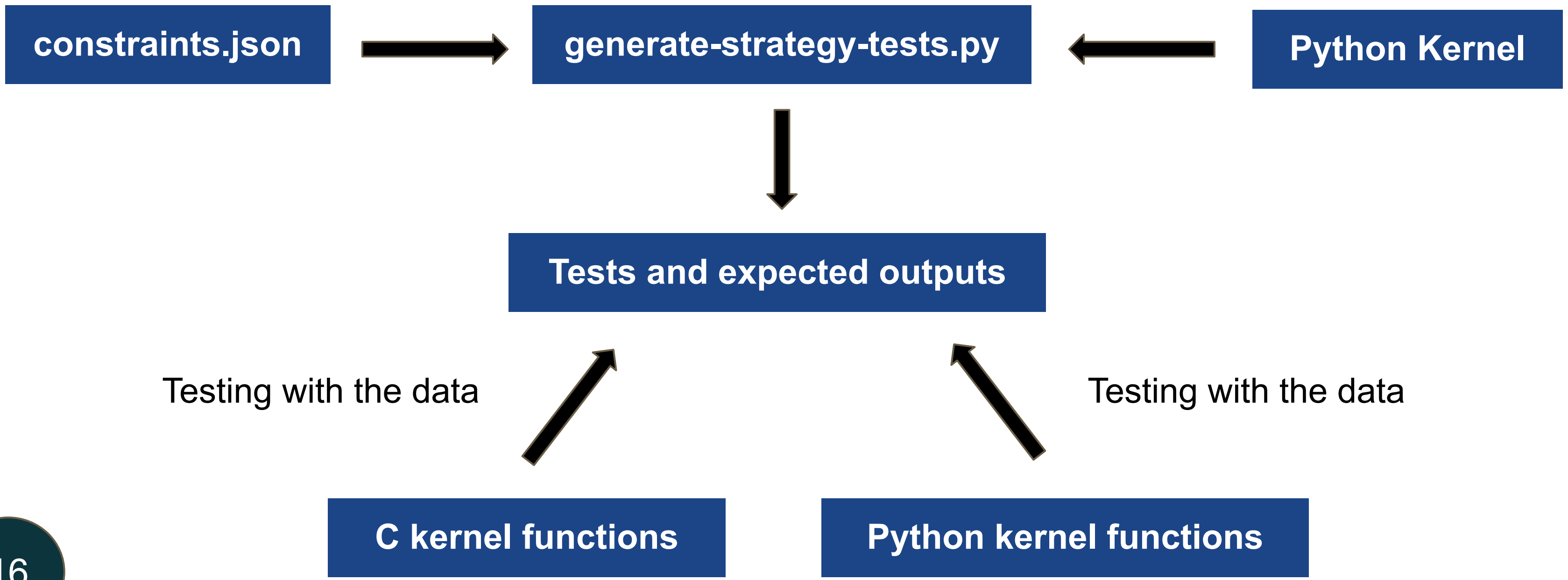
Let’s Run It

A well organized statistical result!!



```
============================================================== Hypothesis Statistics ==============================================================

test_property.py::test_verify_sum_of_numbers:

  - during reuse phase (0.00 seconds):
    - Typical runtimes: ~ 1ms, ~ 37% in data generation
    - 1 passing examples, 0 failing examples, 0 invalid examples

  - during generate phase (1.30 seconds):
    - Typical runtimes: ~ 1ms, ~ 38% in data generation
    - 499 passing examples, 0 failing examples, 0 invalid examples

  - Stopped because settings.max_examples=500


================================================================ 1 passed in 1.36s ================================================================
santam@Santam:~/Documents/Projects/test/slides$ 
```

The Approach



An overview

- Unit tests may leave some corner cases untested which can be found out using property based test.
- The awkward array creates a python kernel which is a specification used to auto generating tests.
- The hypothesis library can be used to get a well documented result of test cases.

Some resources

Hypothesis- https://hypothesis.readthedocs.io/en/latest/index.html#

Awkward Array- https://github.com/scikit-hep/awkward-1.0

The Kernel Specification-
https://github.com/scikit-hep/awkward-1.0/blob/main/kernel-specification.yml

The generate tests script-
https://github.com/SantamRC/awkward-1.0/blob/main/dev/generate-tests.py

A Special Mention to Jim Pivarski and Ianna Osborne

Thank You!!

https://github.com/SantamRC

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