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AE4B99RPH: Problem Solving and Games Automated Tests. Test-Driven Development.

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Motivation

Feedback from the first lab test

Test it in Python shell

Test it when you run the module

Test it with the help of testing tools

Testing

Test-Driven Development

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Task: Equip class `MyVector` with the following methods:

- ✓ `__add__(self, other)`: addition of 2 vectors
- ✓ `norm(self)`: the Euclidean norm (length) of the vector

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Mistakes more common than expected:

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- ✓ The methods were not named `__add__()` and `norm()`.
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- ✓ The source code did not get the indentation (structure) right.

Trivial failures to fulfill the given specifications!

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How to test your own code?

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Run the Python shell and try to use the code as expected:

```
>>> from vectors import MyVector
>>> a = MyVector([1,1,1])
>>> b = MyVector([1,2,3])
>>> c = a+b
>>> type(c)
<class 'vectors.MyVector'>
>>> c.get_vector()
[2, 3, 4]
```

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```

- ✓ You would detect all the above mentioned mistakes.
- ✓ Sometimes you have to change the working directory (`import os; os.chdir()`).
- ✓ Issues with re-importing already imported module:
 - ✗ Python 2x: `reload(module)`
 - ✗ Python 3x: `import imp; imp.reload(module)`
 - ✗ ...yet, it is not a good solution.
 - ✗ Reliable solution: restart the shell.

Test it when you run the module

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Test it when you run the module

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Test-Driven Development

Take advantage of `if __name__ == '__main__':` to run the tests:

```
if __name__ == "__main__":  
    from vectors import MyVector  
    a = MyVector([1,1,1])  
    b = MyVector([1,2,3])  
    c = a+b  
    print(type(c))  
    print(c.get_vector())
```

Test it when you run the module

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Take advantage of `if __name__ == '__main__':` to run the tests:

```
if __name__ == "__main__":  
    from vectors import MyVector  
    a = MyVector([1,1,1])  
    b = MyVector([1,2,3])  
    c = a+b  
    print(type(c))  
    print(c.get_vector())
```

- ✓ No need to worry about the working directory.
- ✓ Your “test” will work even without the explicit module import — if the module name is wrong, we can overlook it.
- ✓ However, the import can be used explicitly. It does not harm and the wrong module name will be discovered.

Test it with the help of testing tools

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Test-Driven Development

Modules for automated testing:

- ✓ doctest, unittest, or other frameworks
- ✓ you can run a lot of tests at once with all the results nicely summarized

Motivation

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Testing

Programmer's testing

Automated tests:

F.I.R.S.T.

Doctest module

xUnit Framework

Test-Driven

Development

Automated testing

Based on

**Gerard Meszarosz: *xUnit Test Patterns: Refactoring Test Code*,
Addison-Wesley, 2007.**

Testing

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Testing from the QA team point of view:

- ✓ Ensure that the code fulfills customer requirements and does not contain bugs.
- ✓ Test after the code is complete.
- ✓ The feedback is too late.

Testing

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Testing from the QA team point of view:

- ✓ Ensure that the code fulfills customer requirements and does not contain bugs.
- ✓ Test after the code is complete.
- ✓ The feedback is too late.

Testing from the programmer's point of view (unit tests, integration tests):

- ✓ Ensure that the unit I am working on right now fulfills the requirements that emerged as a result of the application architecture design.
- ✓ Test during development.
- ✓ The feedback comes much sooner.

Programmer's testing

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Development

Hopefully you do at least some testing during development.

```
if __name__ == "__main__":
    pg = PrimesGenerator()
    print("Primes up to 0: ", pg.get_primes_up_to(0))
    print("Primes up to 1: ", pg.get_primes_up_to(1))
    print("Primes up to 2: ", pg.get_primes_up_to(2))
    print("Primes up to 3: ", pg.get_primes_up_to(3))
    print("Primes up to 4: ", pg.get_primes_up_to(4))
    print("Primes up to 5: ", pg.get_primes_up_to(5))
    print("Primes up to 6: ", pg.get_primes_up_to(6))
    print("Primes up to 20: ", pg.get_primes_up_to(20))
```

But you have to check the output:

```
Primes up to 0: []
Primes up to 1: []
Primes up to 2: [2]
Primes up to 3: [2, 3]
Primes up to 4: [2, 3]
Primes up to 5: [2, 3, 5]
Primes up to 6: [2, 3, 5]
Primes up to 20: [2, 3, 5, 7, 11, 13, 17, 19]
Primes up to 100: [2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97]
>>>
```

Automated tests: F.I.R.S.T.

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Development

Automated tests should be

Fast. If they are not fast, you will not run them often. If you will not run them often, you will not discover bugs in time.

Automated tests: F.I.R.S.T.

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Fast. If they are not fast, you will not run them often. If you will not run them often, you will not discover bugs in time.

Independent. The test should be able to run in isolation and in any order. If they are not independent, a bug in a single test will trigger a series of bugs in other tests. Finding the bug will be harder.

Automated tests: F.I.R.S.T.

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Repeatable. Anybody should be able to repeat the tests anywhere with the same results.

Automated tests: F.I.R.S.T.

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Repeatable. Anybody should be able to repeat the tests anywhere with the same results.

Self-validating. The tests should either pass or fail. You shouldn't be forced to parse some textual output of results to see if the test passed, otherwise you will not want to run the tests so often.

Automated tests: F.I.R.S.T.

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Self-validating. The tests should either pass or fail. You shouldn't be forced to parse some textual output of results to see if the test passed, otherwise you will not want to run the tests so often.

Timely. The tests should be written in time, ideally before the production code. If you write them after the production code, the code is often hard to test. If writing the tests is hard, you will not want to write them.

Doctest module

Motivation

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F.I.R.S.T.

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xUnit Framework

Test-Driven

Development

- ✓ you have already seen it during lectures and labs
- ✓ special to Python (correct me if I am wrong)
- ✓ very handy for simple tests with little setup and cleanup, unnatural for more complex tests

```
class PrimesGenerator:
    """Prime numbers generator.

    >>> pg = PrimesGenerator()
    >>> pg.get_primes_up_to(1)
    []
    >>> pg.get_primes_up_to(2)
    [2]
    >>> pg.get_primes_up_to(3)
    [2, 3]
    >>> pg.get_primes_up_to(4)
    [2, 3]
    >>> pg.get_primes_up_to(5)
    [2, 3, 5]
    >>> pg.get_primes_up_to(7)
    [2, 3, 5, 7]
    >>> pg.get_primes_up_to(20)
    [2, 3, 5, 7, 11, 13, 17, 19]
    """
    ...

if __name__ == "__main__":
    import doctest
    doctest.testmod()
```

xUnit Framework

Motivation

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Doctest module

xUnit Framework

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Development

- ✓ Standard unit testing framework
- ✓ Implemented in many languages (learn it once, use it anywhere)
- ✓ Python implementation: module `unittest`.

xUnit Framework

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Doctest module

xUnit Framework

Test-Driven

Development

- ✓ Standard unit testing framework
- ✓ Implemented in many languages (learn it once, use it anywhere)
- ✓ Python implementation: module `unittest`.

```
import unittest
from primes3 import PrimesGenerator

class PrimesGeneratorTest(unittest.TestCase):

    known_values = ( ( 0, [] ),
                    ( 1, [] ),
                    ( 2, [2] ),
                    ( 3, [2,3] ),
                    ( 4, [2,3] ),
                    ( 5, [2,3,5] ),
                    ( 7, [2,3,5,7] ),
                    ( 20, [2,3,5,7,11,13,17,19] ) )

    def setUp(self):
        self.pg = PrimesGenerator()

    def test_get_primes_up_to(self):
        for limit, expected in self.known_values:
            observed = self.pg.get_primes_up_to(limit)
            self.assertEqual(observed, expected)

    ...

if __name__ == '__main__':
    unittest.main()
```

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TDD: Test-Driven
Development

TDD Example

TDD 1

TDD 2

TDD 3

TDD 4

TDD 5

TDD 6

TDD 8

TDD 9

More complex case: class
Game

TDD: Conclusions

Test-Driven Development

TDD: Test-Driven Development

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TDD Example

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TDD: Conclusions

Three rules of TDD:

1. Do not write any production code until you have first written a failing unit test.
2. Do not write more of a unit test than is sufficient to fail, and not compiling is failing.
3. Do not write more production code than is sufficient to pass the currently failing unit test.

TDD: Test-Driven Development

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TDD: Test-Driven
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TDD Example

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2. Do not write more of a unit test than is sufficient to fail, and not compiling is failing.
3. Do not write more production code than is sufficient to pass the currently failing unit test.

The result of these rules:

- ✓ a very short cycle in which you alternate between
 - ✗ the role of a customer who says *what* shall be done (you write a test), and
 - ✗ the role of a programmer who says *how* it shall be done (you write or modify production code).
- ✓ Tests and production code are written together (tests a few seconds sooner).
- ✓ Tests then cover the whole production code!

TDD Example

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TDD: Test-Driven
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TDD: Conclusions

Create a function that factorizes a natural number into a product of prime factors.

- ✓ Input: the number to be factorized
- ✓ Output: a list of primes whose product is equal to the given number

TDD Example

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TDD: Test-Driven
Development

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TDD: Conclusions

Create a function that factorizes a natural number into a product of prime factors.

- ✓ Input: the number to be factorized
- ✓ Output: a list of primes whose product is equal to the given number

How would you proceed? Suppose we already have class `PrimeGenerator...`

TDD Example: Initial phase

Create the test file, test_factorize.py

```
import unittest
from factorization import factorize
```

TDD Example: Initial phase

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After executing test_factorize.py:

```
Traceback (most recent call last):
  File "<string>", line 2, in <fragment>
builtins.ImportError: No module named factorization
```

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Update factorization.py:

```
def factorize():
    pass
```

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After executing test_factorize.py:

```
--- Žádný výstup, kód bez chyby. ---
```

TDD Example: Initial phase

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After executing `test_factorize.py`:

```
--- Žádný výstup, kód bez chyby. ---
```

Update `test_factorize.py`

```
import unittest
from factorization import factorize

class FactorizeTest(unittest.TestCase):
    pass

if __name__=="__main__":
    unittest.main()
```


TDD Example: Initial phase

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```

Update test_factorize.py

```
import unittest
from factorization import factorize

class FactorizeTest(unittest.TestCase):
    pass

if __name__=="__main__":
    unittest.main()
```

After executing test_factorize.py:

```
-----
Ran 0 tests in 0.000s

OK
builtins.SystemExit: False
```

TDD Example: Factorize number 2

Update test_factorize.py

```
class FactorizeTest(unittest.TestCase):  
  
    def test_two(self):  
        observed = factorize(2)  
        self.assertEqual(observed, [2])
```

TDD Example: Factorize number 2

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class FactorizeTest(unittest.TestCase):  
  
    def test_two(self):  
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```

After executing test_factorize.py:

```
E  
=====ERROR: test_one (__main__.FactorizeTest)  
-----  
Traceback (most recent call last):  
  File "<wingdb_compile>", line 7, in test_one  
TypeError: factorize() takes no arguments (1 given)  
-----  
Ran 1 test in 0.000s
```

Update factorization.py:

```
def factorize(multiple):  
    pass
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Ran 1 test in 0.000s
```

Update factorization.py:

```
def factorize(multiple):  
    pass
```

```
F  
=====FAIL: test_one (__main__.FactorizeTest)  
-----  
Traceback (most recent call last):  
  File "<wingdb_compile>", line 8, in test_one  
AssertionError: None != [2]  
-----  
Ran 1 test in 0.000s
```

TDD Example: Factorize number 2

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class FactorizeTest(unittest.TestCase):  
  
    def test_two(self):  
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After executing test_factorize.py:

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F  
=====FAIL: test_one (__main__.FactorizeTest)  
-----  
Traceback (most recent call last):  
  File "<wingdb_compile>", line 8, in test_one  
AssertionError: None != [2]  
-----  
Ran 1 test in 0.000s
```

Update factorization.py:

```
def factorize(multiple):  
    return [2]
```

TDD Example: Factorize number 2

Update test_factorize.py

```
class FactorizeTest(unittest.TestCase):  
  
    def test_two(self):  
        observed = factorize(2)  
        self.assertEqual(observed, [2])
```

After executing test_factorize.py:

```
E  
=====ERROR: test_one (__main__.FactorizeTest)  
-----  
Traceback (most recent call last):  
  File "<wingdb_compile>", line 7, in test_one  
TypeError: factorize() takes no arguments (1 given)  
-----  
Ran 1 test in 0.000s
```

Update factorization.py:

```
def factorize(multiple):  
    pass
```

```
F  
=====FAIL: test_one (__main__.FactorizeTest)  
-----  
Traceback (most recent call last):  
  File "<wingdb_compile>", line 8, in test_one  
AssertionError: None != [2]  
-----  
Ran 1 test in 0.000s
```

Update factorization.py:

```
def factorize(multiple):  
    return [2]
```

```
.  
-----  
Ran 1 test in 0.000s
```

TDD Example: Factorize number 3

Update test_factorize.py

```
def test_three(self):  
    observed = factorize(3)  
    self.assertEqual(observed, [3])
```

TDD Example: Factorize number 3

Update test_factorize.py

```
def test_three(self):  
    observed = factorize(3)  
    self.assertEqual(observed, [3])
```

After executing test_factorize.py:

```
F.  
===== FAIL: test_three (__main__.FactorizeTest)  
-----  
Traceback (most recent call last):  
  File "<wingdb_compile>", line 12, in test_three  
AssertionError: Lists differ: [2] != [3]  
  
First differing element 0:  
2  
3  
  
- [2]  
+ [3]  
  
-----  
Ran 2 tests in 0.016s
```

Update factorization.py:

```
def factorize(multiple):  
    return [multiple]
```


TDD Example: Factorize number 3

Update test_factorize.py

```
def test_three(self):  
    observed = factorize(3)  
    self.assertEqual(observed, [3])
```

After executing test_factorize.py:

```
F.  
===== FAIL: test_three (__main__.FactorizeTest)  
-----  
Traceback (most recent call last):  
  File "<wingdb_compile>", line 12, in test_three  
AssertionError: Lists differ: [2] != [3]  
  
First differing element 0:  
2  
3  
  
- [2]  
+ [3]  
  
-----  
Ran 2 tests in 0.016s
```

Update factorization.py:

```
def factorize(multiple):  
    return [multiple]
```

```
..  
-----  
Ran 2 tests in 0.000s
```

TDD Example: Factorize number 4

Update test_factorize.py

```
def test_four(self):  
    observed = factorize(4)  
    self.assertEqual(observed, [2,2])
```

TDD Example: Factorize number 4

Update test_factorize.py

```
def test_four(self):
    observed = factorize(4)
    self.assertEqual(observed, [2,2])
```

After executing test_factorize.py:

```
F..
=====
FAIL: test_four (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 16, in test_four
AssertionError: Lists differ: [4] != [2, 2]
[...snip...]
-----
Ran 3 tests in 0.000s
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    while multiple % 2 == 0:
        factors.append(2)
        multiple /= 2
    return factors
```

TDD Example: Factorize number 4

Update test_factorize.py

```
def test_four(self):
    observed = factorize(4)
    self.assertEqual(observed, [2,2])
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    while multiple % 2 == 0:
        factors.append(2)
        multiple /= 2
    return factors
```

After executing test_factorize.py:

```
F..
=====
FAIL: test_four (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 16, in test_four
AssertionError: Lists differ: [4] != [2, 2]
[...snip...]
-----
Ran 3 tests in 0.000s
```

```
.F.
=====
FAIL: test_three (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 12, in test_three
AssertionError: Lists differ: [] != [3]
[...snip...]
-----
Ran 3 tests in 0.016s
```

TDD Example: Factorize number 4

Update test_factorize.py

```
def test_four(self):
    observed = factorize(4)
    self.assertEqual(observed, [2,2])
```

After executing test_factorize.py:

```
F..
=====
FAIL: test_four (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 16, in test_four
AssertionError: Lists differ: [4] != [2, 2]
[...snip...]
-----
Ran 3 tests in 0.000s
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    while multiple % 2 == 0:
        factors.append(2)
        multiple /= 2
    return factors
```

```
.F.
=====
FAIL: test_three (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 12, in test_three
AssertionError: Lists differ: [] != [3]
[...snip...]
-----
Ran 3 tests in 0.016s
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    while multiple % 2 == 0:
        factors.append(2)
        multiple /= 2
    if multiple != 1:
        factors.append(multiple)
    return factors
```

TDD Example: Factorize number 4

Update test_factorize.py

```
def test_four(self):
    observed = factorize(4)
    self.assertEqual(observed, [2,2])
```

After executing test_factorize.py:

```
F..
=====
FAIL: test_four (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 16, in test_four
AssertionError: Lists differ: [4] != [2, 2]
[...snip...]
-----
Ran 3 tests in 0.000s
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    while multiple % 2 == 0:
        factors.append(2)
        multiple /= 2
    return factors
```

```
.F.
=====
FAIL: test_three (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 12, in test_three
AssertionError: Lists differ: [] != [3]
[...snip...]
-----
Ran 3 tests in 0.016s
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    while multiple % 2 == 0:
        factors.append(2)
        multiple /= 2
    if multiple != 1:
        factors.append(multiple)
    return factors
```

```
...
-----
Ran 3 tests in 0.000s
```

TDD Example: Factorize number 5

Update test_factorize.py

```
def test_five(self):  
    observed = factorize(5)  
    self.assertEqual(observed, [5])
```

TDD Example: Factorize number 5

Update test_factorize.py

```
def test_five(self):  
    observed = factorize(5)  
    self.assertEqual(observed, [5])
```

After executing test_factorize.py:

```
.....  
-----  
Ran 4 tests in 0.000s
```


TDD Example: Factorize number 6

Update test_factorize.py

```
def test_six(self):  
    observed = factorize(6)  
    self.assertEqual(observed, [2,3])
```

TDD Example: Factorize number 6

Update test_factorize.py

```
def test_six(self):  
    observed = factorize(6)  
    self.assertEqual(observed, [2,3])
```

After executing test_factorize.py:

```
.....  
-----  
Ran 5 tests in 0.000s
```

TDD Example: Factorize number 6

Update test_factorize.py

```
def test_six(self):  
    observed = factorize(6)  
    self.assertEqual(observed, [2,3])
```

After executing test_factorize.py:

```
.....  
-----  
Ran 5 tests in 0.000s
```

Test for factorizing number 7 is left out, it is the same case as for numbers 3 and 5.

TDD Example: Factorize number 8

Update test_factorize.py

```
def test_eight(self):  
    observed = factorize(8)  
    self.assertEqual(observed, [2,2,2])
```

TDD Example: Factorize number 8

Update test_factorize.py

```
def test_eight(self):  
    observed = factorize(8)  
    self.assertEqual(observed, [2,2,2])
```

After executing test_factorize.py:

```
.....  
-----  
Ran 6 tests in 0.000s
```

TDD Example: Factorize number 9

Update test_factorize.py

```
def test_nine(self):  
    observed = factorize(9)  
    self.assertEqual(observed, [3,3])
```

TDD Example: Factorize number 9

Update test_factorize.py

```
def test_nine(self):  
    observed = factorize(9)  
    self.assertEqual(observed, [3,3])
```

After executing test_factorize.py:

```
...F...  
===== FAIL: test_nine (__main__.FactorizeTest)  
-----  
Traceback (most recent call last):  
  File "<wingdb_compile>", line 32, in test_nine  
AssertionError: Lists differ: [9] != [3, 3]  
[...snip...]  
-----  
Ran 7 tests in 0.000s
```

TDD Example: Factorize number 9

Update test_factorize.py

```
def test_nine(self):
    observed = factorize(9)
    self.assertEqual(observed, [3,3])
```

After executing test_factorize.py:

```
...F...
=====
FAIL: test_nine (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 32, in test_nine
AssertionError: Lists differ: [9] != [3, 3]
[...snip...]
-----
Ran 7 tests in 0.000s
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    for factor in range(2,multiple+1):
        while multiple % factor == 0:
            factors.append(factor)
            multiple /= factor
    return factors
```


TDD Example: Factorize number 9

Update test_factorize.py

```
def test_nine(self):
    observed = factorize(9)
    self.assertEqual(observed, [3,3])
```

After executing test_factorize.py:

```
...F...
=====
FAIL: test_nine (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 32, in test_nine
AssertionError: Lists differ: [9] != [3, 3]
[...snip...]
-----
Ran 7 tests in 0.000s
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    for factor in range(2,multiple+1):
        while multiple % factor == 0:
            factors.append(factor)
            multiple /= factor
    return factors
```

```
.....
-----
Ran 7 tests in 0.015s
```

TDD Example: Factorize number 9

Update test_factorize.py

```
def test_nine(self):
    observed = factorize(9)
    self.assertEqual(observed, [3,3])
```

After executing test_factorize.py:

```
...F...
=====
FAIL: test_nine (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 32, in test_nine
AssertionError: Lists differ: [9] != [3, 3]
[...snip...]
-----
Ran 7 tests in 0.000s
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    for factor in range(2,multiple+1):
        while multiple % factor == 0:
            factors.append(factor)
            multiple /= factor
    return factors
```

```
.....
-----
Ran 7 tests in 0.015s
```

-
- ✓ Are you able to come up with another failing test?

TDD Example: Factorize number 9

Update test_factorize.py

```
def test_nine(self):
    observed = factorize(9)
    self.assertEqual(observed, [3,3])
```

After executing test_factorize.py:

```
...F...
=====
FAIL: test_nine (__main__.FactorizeTest)
-----
Traceback (most recent call last):
  File "<wingdb_compile>", line 32, in test_nine
AssertionError: Lists differ: [9] != [3, 3]
[...snip...]
-----
Ran 7 tests in 0.000s
```

Update factorization.py:

```
def factorize(multiple):
    factors = []
    for factor in range(2,multiple+1):
        while multiple % factor == 0:
            factors.append(factor)
            multiple /= factor
    return factors
```

```
.....
-----
Ran 7 tests in 0.015s
```

- ✓ Are you able to come up with another failing test?
- ✓ Note that we actually do not need any PrimeGenerator; if we decided to use it, the code may be more complex!

More complex case: class Game

Motivation

Testing

Test-Driven
Development

TDD: Test-Driven
Development

TDD Example

TDD 1

TDD 2

TDD 3

TDD 4

TDD 5

TDD 6

TDD 8

TDD 9

More complex case: class
Game

TDD: Conclusions

Typical use of class Game:

```
>>> g = Game(playerA, playerB, payoff_matrix, n_iterations)
>>> g.run()
>>> g.get_players_payoffs()
```

What are the class responsibilities we want to test?

More complex case: class Game

Motivation

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TDD: Test-Driven
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TDD Example

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More complex case: class
Game

TDD: Conclusions

Typical use of class Game:

```
>>> g = Game(playerA, playerB, payoff_matrix, n_iterations)
>>> g.run()
>>> g.get_players_payoffs()
```

What are the class responsibilities we want to test?

- ✓ Method `get_players_payoffs()` returns `(None, None)` before executing method `run()`.

More complex case: class Game

Motivation

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TDD: Test-Driven
Development

TDD Example

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More complex case: class
Game

TDD: Conclusions

Typical use of class Game:

```
>>> g = Game(playerA, playerB, payoff_matrix, n_iterations)
>>> g.run()
>>> g.get_players_payoffs()
```

What are the class responsibilities we want to test?

- ✓ Method `get_players_payoffs()` returns `(None, None)` before executing method `run()`.
- ✓ Method `run()` calls methods `move()` and `record_opponents_move()` of both `Players` exactly `n_iterations` times.
- ✓ Method `run()` calls methods `move()` and `record_opponents_move()` alternatively, it begins with method `move()`.
- ✓ Method `run()` is fair to both the `Players`, i.e. it does not pass the current move of one player to the other player.
- ✓ ...

TDD: Conclusions

Motivation

Testing

Test-Driven
Development

TDD: Test-Driven
Development

TDD Example

TDD 1

TDD 2

TDD 3

TDD 4

TDD 5

TDD 6

TDD 8

TDD 9

More complex case: class
Game

TDD: Conclusions

Tests

- ✓ serve as specification by example.
- ✓ serve as documentation.
- ✓ help to understand the algorithm.
- ✓ help to prevent unnecessary complexity of the code.
- ✓ determine when we are “Done.”
- ✓ help to prevent new bugs when modifying the code.



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