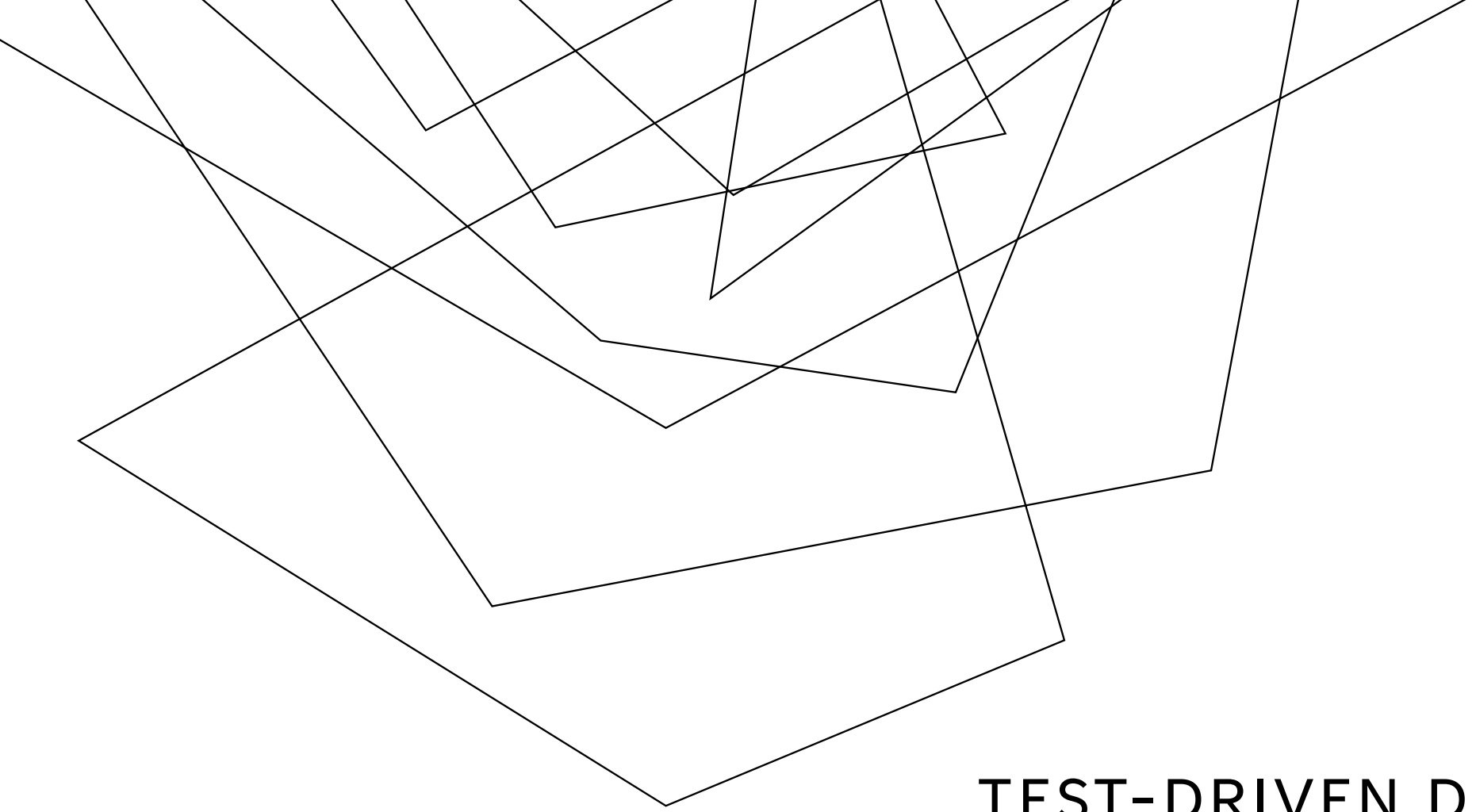


TEST-DRIVEN DEVELOPMENT FOR ACADEMIC SIMULATION

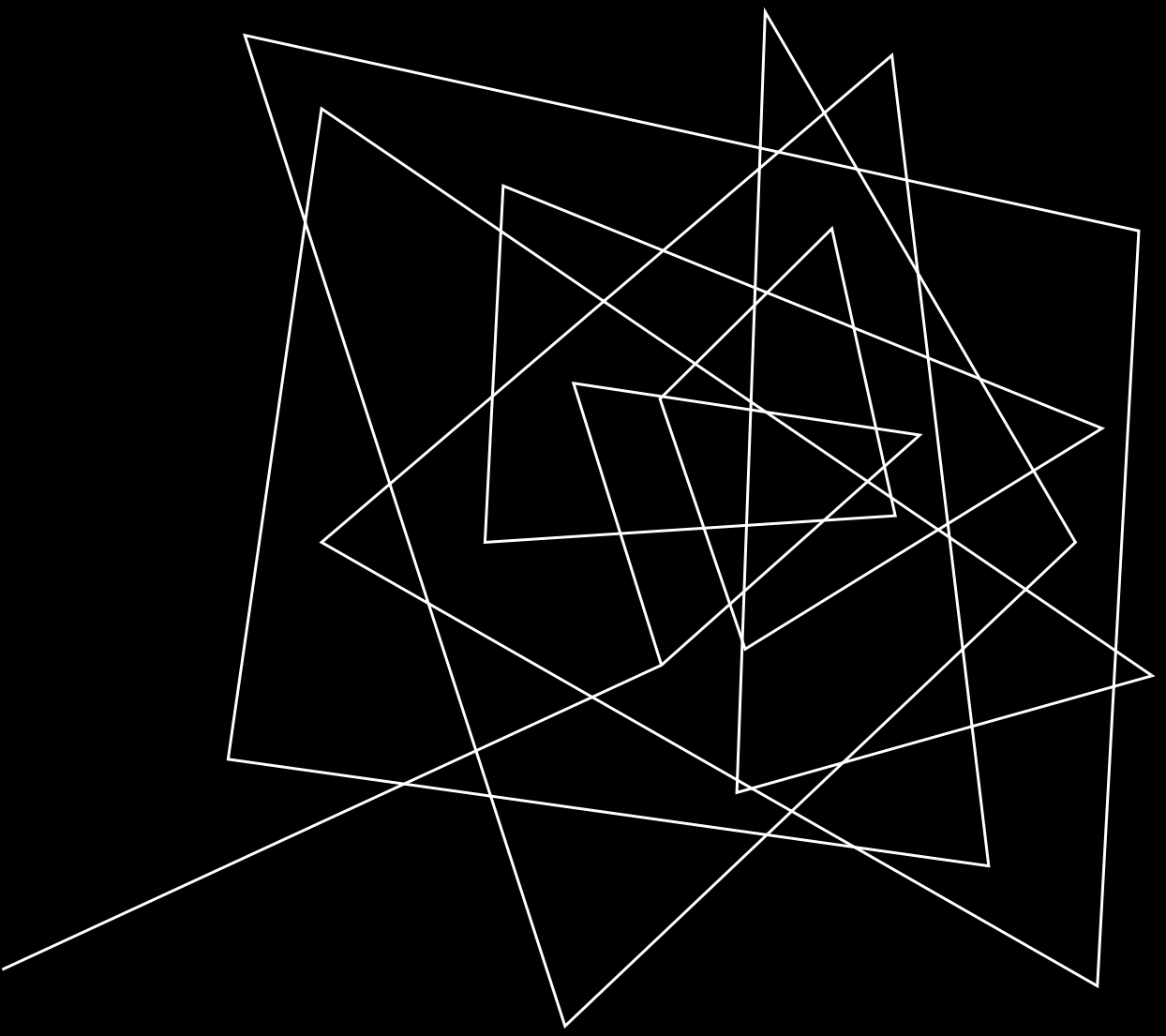
Paul A. Monderkamp

AGENDA

brief presentation

- Introduction
  1. why/what is test in general
  2. what are unit-tests
  3. what is test-driven development
- What is test-driven development
  1. workflow
  2. example
- 4 reasons for test-driven development

workshop



Introduction

1. why/what is test in general
2. what are unit-tests
3. what is test-driven development

INTRODUCTION—WHY TEST IN GENERAL?

Errors may lead to catastrophe

INTRODUCTION—WHY TEST IN GENERAL?

The New York Times

Airline Blames Bad Software in San Francisco Crash

Cause	Airworthiness revoked after recurring flight control failure
Budget	• direct costs: US$20 billion[2] • indirect costs: US$60 billion[2]
Deaths	346 total: • 189 on Lion Air Flight 610 • 157 on Ethiopian Airlines Flight 302

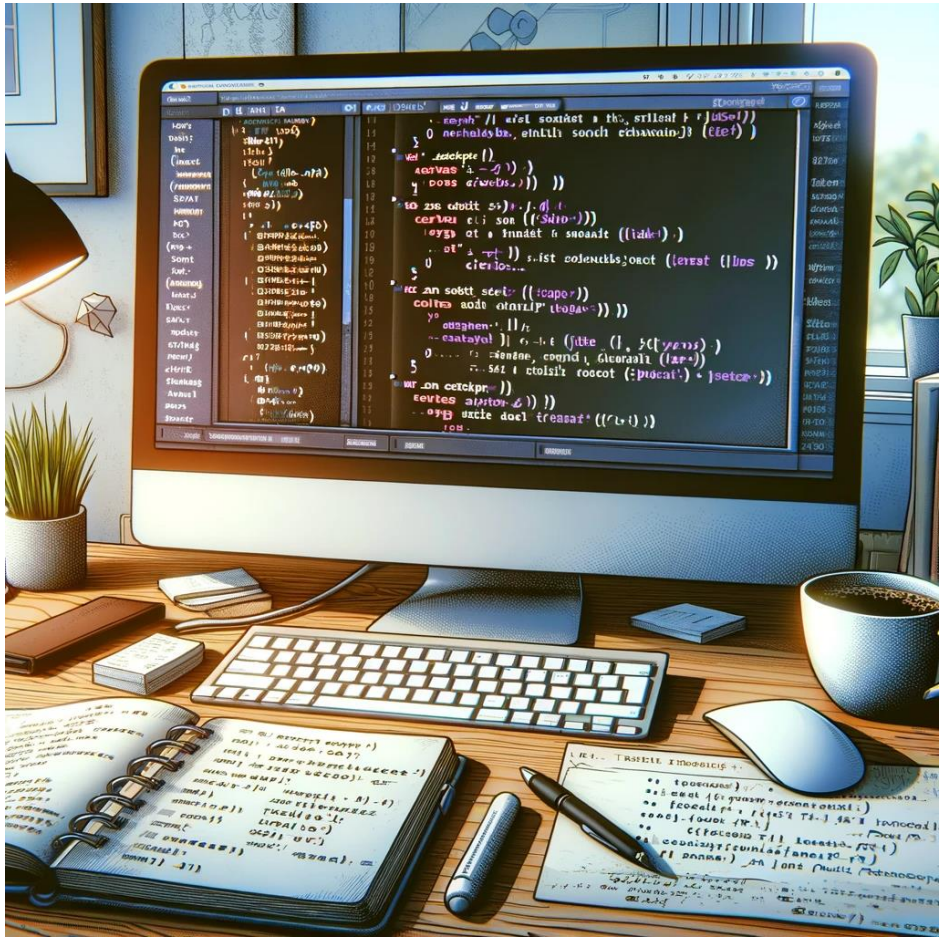
"The MCAS software didn't have any basic sanity checks to confirm the data was bad," Travis said. What's even more astounding is that Boeing is still trying to fix MCAS while all of its 737 MAX planes are grounded around the globe, he added. That includes 737 MAX planes used by American and Southwest in the U.S. "I don't understand why Boeing is hell bent on fixing MCAS as opposed to retreating and taking another tack."

Errors do lead to catastrophe

INTRODUCTION—WHAT IS TEST IN GENERAL?

Test is quality control

INTRODUCTION—WHAT ARE UNIT-TESTS?



INTRODUCTION—WHAT ARE UNIT-TESTS?

```
def mySqrt(x):
        … #implementation
```

```
#test
if (mySqrt(2.) - 1.414213) > 1E-6: print(„x = 2.: test failed“)
elif (mySqrt(1.) != 1.)          : print(„x = 1.: test failed“)
elif !(np.isnan(mySqrt(-1))      : print(„x = -1: test failed“)
else:                            : print(„all tests passed“)
```

Test a piece of code with examples

INTRODUCTION—WHAT ARE UNIT-TESTS?

```
def mySqrt(x):
        … #implementation
```

```
ASSERT_DOUBLE_EQ(mySqrt(2.), 1.4142135623730950488016887   , „x=2“)
ASSERT_DOUBLE_EQ(mySqrt(1.), 1.                            , „x=1“)
ASSERT_FALSE(mySqrt(-1.)                                   , „x=-1“)
```

Normally use a software-toolkit

INTRODUCTION—WHAT ARE UNIT-TESTS?

```
class sphere:
        def __init__(self, X, Y, R):
                self.x = X
                self.y = Y
                self.r = R
```

Usually more complicated examples

INTRODUCTION—WHAT ARE UNIT-TESTS?

```
class sphere:
        def __init__(self, X, Y, R):
                self.x = X
                …

        def overlap(self, anotherSphere):
                #implementation
```

Have some member-function

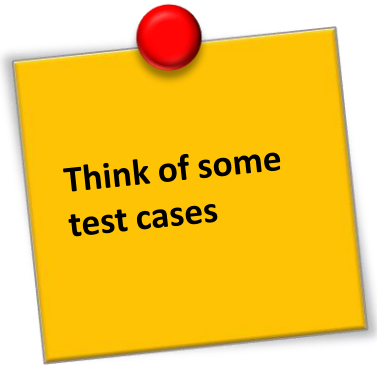
INTRODUCTION—WHAT ARE UNIT-TESTS?

```
class sphere:
        def __init__(self, X, Y, R):
                self.x = X
                …

        def overlap(self, anotherSphere):
                #implementation
```

```
def testSpheresDoOverlap():
        sphere1 = sphere(0., 0., 1.)
        sphere2 = sphere(1., 1., 1.)
        assertTrue(sphere1.overlap(sphere2))
        assertTrue(sphere2.overlap(sphere1))

def testSpheresDontOverlap():
        sphere1 = sphere(0., 0., 1.)
        sphere2 = sphere(2., 2., 1.)
        assertFalse(sphere1.overlap(sphere2))
        assertFalse(sphere2.overlap(sphere1))
```



INTRODUCTION—WHAT ARE UNIT-TESTS?

```
class sphere:
        def __init__(self, X, Y, R):
                self.x = X
                …

        def overlap(self, anotherSphere):
                #implementation
```

```
def testSpheresDoOverlap():
        sphere1 = sphere(0., 0., 1.)
        sphere2 = sphere(sqrt(2), sqrt(2), 1.)
        assertTrue(sphere1.overlap(sphere2))
        assertTrue(sphere2.overlap(sphere1))
```

```
def testSpheresDoOverlap():
        sphere1 = sphere(0., 0., 1.)
        sphere2 = sphere(1., 1., 1.)
        assertTrue(sphere1.overlap(sphere2))
        assertTrue(sphere2.overlap(sphere1))

def testSpheresDontOverlap():
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```

INTRODUCTION—WHAT ARE UNIT-TESTS?

```
class sphere:
        def __init__(self, X, Y, R):
                self.x = X
                …

        def overlap(self, anotherSphere):
                …
```

```
def testSpheresDoOverlap():
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```
def testSpheresDoOverlap():
        sphere1 = sphere(0., 0., 1.)
        sphere2 = sphere(sqrt(2), sqrt(2), 1.)
        assertTrue(sphere1.overlap(sphere2))
        assertTrue(sphere2.overlap(sphere1))
```

```
if __name__ == „__main__“:
        #runAllTests
```

All tests are called somehow (very often)

INTRODUCTION—WHAT ARE UNIT-TESTS?

```
class Date:
        def __init__(self, YEAR, MONTH, DAY):
                self.YEAR = YEAR
                …
        def shiftOneMonth():
                …
```

```
def testShiftOctoberToChristmas():
        myDate = Date(2018, 10, 25)
        myDate.shiftOneMonth()
        myDate.shiftOneMonth()
        ASSERT_EQ(myDate, Date(2018, 12, 27))
```

Can involve several steps

INTRODUCTION—WHAT ARE UNIT-TESTS?

```
class ActiveBrownianParticle:
        def __init__(self, v0, Dr):
                self.pos = (0., 0.)
                self.phi = rand()
                …
        def applyNoise(…):
                …
        def propellForward(…):
                …
        def trajectory(…):
                …
```

Soft Matter simulation example

INTRODUCTION—WHAT ARE UNIT-TESTS?

```
class ActiveBrownianParticle:
        def __init__(self, v0, Dr):
                self.pos = (0., 0.)
                self.phi = rand()
                …
```

```
def testFitLinear():
        allTrajectories = []
        for i in range(oneBillionBillion):
                oneParticle = ActiveBrownianParticle(…)
                allTrajectories.append(oneParticle.trajectory(…)
        linearFit = …
        assertTrue(linearFit.fitError < 0.0001)
```

```
def testDifflong():
        allTrajectories = []
        for i in range(oneBillionBillion):
                oneParticle = ActiveBrownianParticle(…)
                allTrajectories.append(oneParticle.trajectory(…)
        Difflong = …
        assertTrue(Difflong*2*Dr/v0^2 -1 < 0.0001)
```

How do deal with randomness

INTRODUCTION—WHAT ARE UNIT-TESTS?

```
class ActiveBrownianParticle:
        def __init__(self, v0, Dr):
                self.pos = (0., 0.)
                self.phi = rand()
                …
```

```
def testFitLinear():
        allTrajectories = []
        for i in range(oneBillionBillion):
                oneParticle = ActiveBrownianParticle(…)
                allTrajectories.append(oneParticle.trajectory(…)
        linearFit = …
        assertTrue(linearFit.fitError < 0.0001)
```

```
def testDifflong():
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        for i in range(oneBillionBillion):
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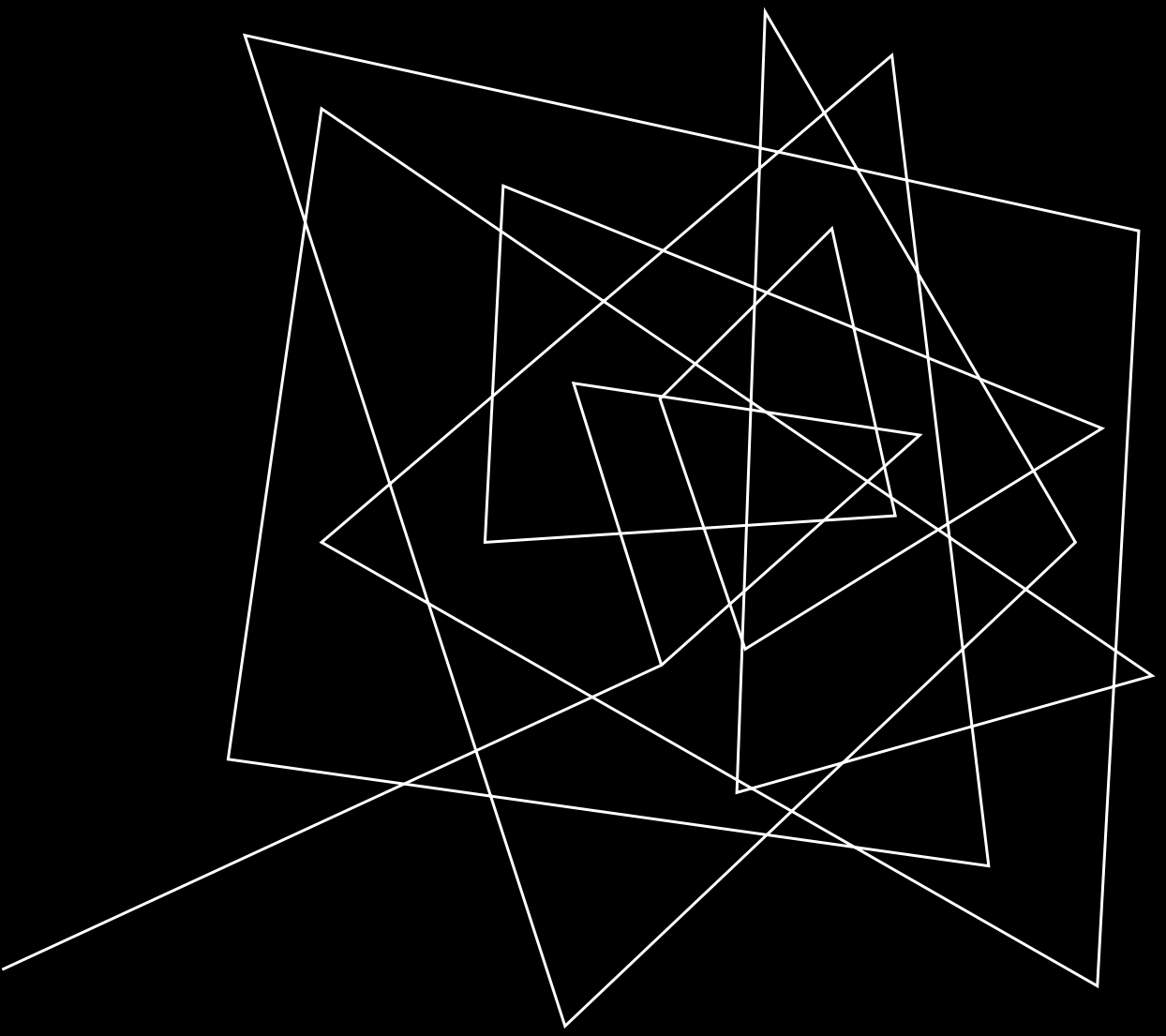
        Difflong = …
        assertTrue(Difflong*2*Dr/v0^2 -1 < 0.0001)
```

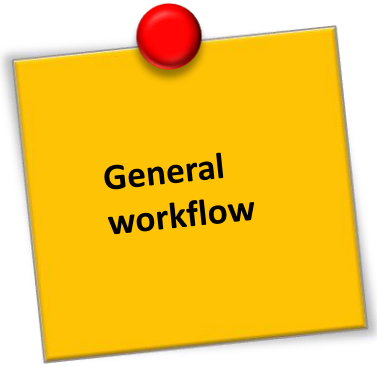


What is test-driven developent?

1. workflow
2. example

WHAT IS TEST-DRIVEN DEVELOPMENT—WORKFLOW

1. Write a shell-implementation for in incrementational expansion of the existing code, which returns a wrong result
2. Write a set of appropriate unit-tests
3. Run all unit-tests and make sure they fail
4. Write the implementation of the code
5. Run all unit-tests and make sure they pass.
   If not, go back to step 4.



WHAT IS TEST-DRIVEN DEVELOPMENT—EXAMPLE—STEP 1: SHELL IMPLEMENTATION

Implementation code

```
class myMathFunctions:
        def __init__(self):
                …
        def mySqrt(self,x):
                return -1
```

Test code

```
import myMathFunctions

if __name__ == „__main__“:
        # do nothing so far
```

Shell implementation

WHAT IS TEST-DRIVEN DEVELOPMENT—EXAMPLE—STEP 2: WRITE TESTS

Implementation code

```
class myMathFunctions:
        def __init__(self):
                …
        def mySqrt(self,x):
                return -1
```

Test code

```
import myMathFunctions
def testSqrtOfOne():
        functionInstance = myMathFunctions()
        ASSERT_EQ(functionInstance.mySqrt(1.), 1., „x=1“)
def testSqrtOfTwo():
        functionInstance = myMathFunctions()
        ASSERT_EQ(functionInstance.mySqrt(2.), 1.414…, „x=2“)
def testSqrtOfZero():
        functionInstance = myMathFunctions()
        ASSERT_EQ(functionInstance.mySqrt(0), 0, „x=0“)
def testSqrtOfNegative():
        functionInstance = myMathFunctions()
        ASSERT_FALSE(functionInstance.mySqrt(-1.), „x=-1“)

if __name__ == „__main__“:
         testSqrtOfOne()
         testSqrtOfTwo()
         testSqrtOfZero()
         testSqrtOfNegative()
```

Write Tests

WHAT IS TEST-DRIVEN DEVELOPMENT—EXAMPLE—STEP 3: RUN ALL TESTS—MAKE SURE THEY FAIL

Implementation code

```
class myMathFunctions:
        def __init__(self):
                …
        def mySqrt(self,x):
                return -1
```

Test code

```
import myMathFunctions
def testSqrtOfOne():
        functionInstance = myMathFunctions()
        ASSERT_EQ(functionInstance.mySqrt(1.), 1., „x=1“)
def testSqrtOfTwo():
        functionInstance = myMathFunctions()
        ASSERT_EQ(functionInstance.mySqrt(2.), 1.414…, „x=2“)
def testSqrtOfZero():
        functionInstance = myMathFunctions()
        ASSERT_EQ(functionInstance.mySqrt(0), 0, „x=0“)
def testSqrtOfNegative():
        functionInstance = myMathFunctions()
        ASSERT_FALSE(functionInstance.mySqrt(-1.), „x=-1“)

if __name__ == „__main__“:
         testSqrtOfOne()
         testSqrtOfTwo()
         testSqrtOfZero()
         testSqrtOfNegative()
```

Run all tests
Make sure they fail

WHAT IS TEST-DRIVEN DEVELOPMENT—EXAMPLE—STEP 4&5: IMPLEMENT FUNCTION AND USE TESTS

Implementation code

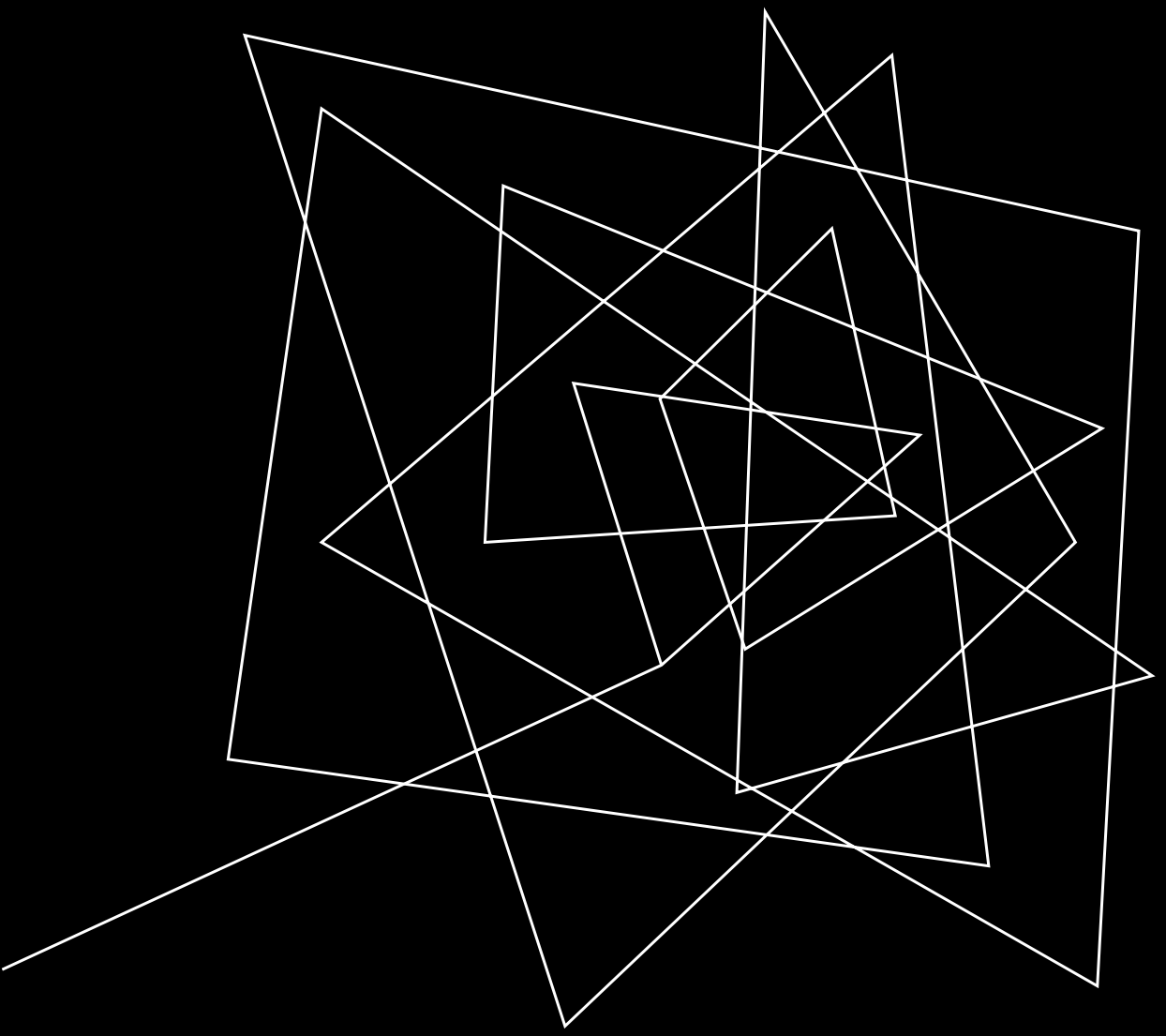
```
class myMathFunctions:
        def __init__(self):
                …
        def mySqrt(self,x):
            if x<1: return NaN
            else:
                for i in range(10):
                    x = NewtonMethodStep(y**2-x)
                return x
```

Test code

```
import myMathFunctions
def testSqrtOfOne():
        functionInstance = myMathFunctions()
        ASSERT_EQ(functionInstance.mySqrt(1.), 1., „x=1“)
def testSqrtOfTwo():
        functionInstance = myMathFunctions()
        ASSERT_EQ(functionInstance.mySqrt(2.), 1.414…, „x=2“)
def testSqrtOfZero():
        functionInstance = myMathFunctions()
        ASSERT_EQ(functionInstance.mySqrt(0), 0, „x=0“)
def testSqrtOfNegative():
        functionInstance = myMathFunctions()
        ASSERT_FALSE(functionInstance.mySqrt(-1.), „x=-1“)

if __name__ == „__main__“:
         testSqrtOfOne()
         testSqrtOfTwo()
         testSqrtOfZero()
         testSqrtOfNegative()
```

Implement the desired functionality



4 reasons for test-driven development:

- confidence and speed
- easier problem solving
- better code
- debugging

4 REASONS—REASON 1: CONFIDENCE AND SPEED

```
def pointsDistance(x,y):
        return (x[0]-y[0])*(x[0]-y[0]) +
               (x[1]-y[1])*(x[1]-y[1]) +
               (x[2]-y[2])*(x[2]-y[2])
```

More confident not to commit errors and therefore faster

4 REASONS—REASON 1: CONFIDENCE AND SPEED

```
def pointsDistance(x,y):
        return (x[0]-y[0])*(x[0]-y[0]) +
               (x[1]-y[1])*(x[1]-y[1]) +
               (x[2]-y[2])*(x[2]-y[2])
```

```
typedef array<double,3> vec3d;
vec3d operator*(const vec3d & myVec, const double scalar) {
        const vec3d result = myVec;
        for (auto &a  : myVec) {
                a *= scalar;
        }
        return result;
```

More confident
in new syntax
Learn more/
More efficient

4 REASONS—REASON 2: EASIER PROBLEM SOLVING

```
class Date:
        def __init__(self, YEAR, MONTH, DAY):
                self.YEAR = YEAR
                …
        def shiftOneMonth():
                …
```

```
def testShiftFebruaryToEaster():
        myDate = Date(2018, 2, 1)
        myDate.shiftOneMonth()
        myDate.shiftOneMonth()
        ASSERT_EQ(myDate, Date(2018, 4, 2))
```

Easier to think concrete;
You can guess

4 REASONS—REASON 3: BETTER CODE

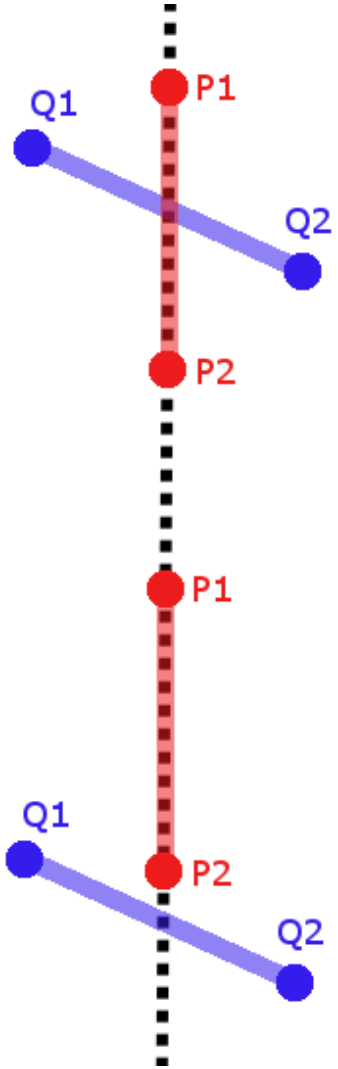
- **Bad code is often difficult to test in hindsight due to little encapsulation, i.e., lot of dependencies => Cant isolate individual units**
- **Since code that is developed test-driven, is already indivually tested, tends to have less of those problems**
- **Easier to understand and therefore debug Because easier units can be understood in isolation**

4 REASONS—REASON 4: DEBUGGING

- **Quality control: Confidence in functionality**
- **automatic bug searching**
- **Can actually use ChatGPT code**

WORKSHOP TIME

WORKSHOP—EXERCISE 2: MATHEMATICAL SOLUTION



Q lies on both sides of P.
Therefore:
(P1-P2)x(Q1-P2) * (P1-P2)x(Q2-P2) <0
x and * signify cross and dot product, respectively

Q lies on both sides of P.
However P does not lie on both sides of Q.
Therefore:
the inequality above must also be true in reverse.