SimplyRhino, London
February 12-14,2020

Python Scripting for Rhino/Grasshopper

Day 3

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DataTree

Example: Create a list of spheres from a tree of points

Please open file **DataTree.gh**

```
import Rhino.Geometry as rg

spheres = []

for points in iPointTree.Branches:
    for point in points:
        spheres.append(rg.Sphere(point, 2.0));

oSpheres = spheres;
```

Example: Create a TREE of spheres from a TREE of points

Please open file **DataTree.gh**

```
import Rhino.Geometry as rg
from Grasshopper import *

sphereTree = DataTree[rg.Sphere]()

for path in iPointTree.Paths:
    points = iPointTree.Branch(path)
    spheres = []
    for point in points:
        spheres.append(rg.Sphere(point, 2.0));
    sphereTree.AddRange(spheres, path)

oSpheres = sphereTree;
```

Parallel Computation

Example: Intersecting MANY lines with a mesh

Please open the file **Parallel Computation.gh**

```
from Rhino.Geometry.Intersect import Intersection
import time
from ghpythonlib import parallel

def ProcessOneCurve(curve):
    return Intersection.MeshPolyline(iMesh, curve.ToPolyline(0.1, 0.1, 0.1, 0.1))[0]

startTime = time.time()

intersectionLists = parallel.run(ProcessOneCurve, iCurves, False)

allIntersections = []

for intersectionList in intersectionLists:
    allIntersections.extend(intersectionList)

endTime = time.time()

print endTime - startTime

oResult = allIntersections
```

Recursion

- Recursive Functions
- Fractals and L-Systems

What is recursion?

Recursion: Defining something using itself

An example (from Maths)

Factorial Definition: n! = 1 * 2 * 3 * 4 * … * (n-1) * n

Alternative definition, using recursion:

1! = 1

and, n! = n * (n-1)!, where n > 1

Why it works?

10! = 10 * 9!

= 10 * 9 * 8!

= …

= 10 * 9 * 8 * … * 1!

Recursion in Programming

- Recursive function: a function that call itself

Hands-on Example:
A recursive function that computes the factorial of a given number

Mathematical definition: $1! = 1$
$n! = n * (n-1)!$, where $n > 1$

A recursive function

```
def Factorial(n):
    if n == 1:
        return 1
    else:
        return n * Factorial(n-1)

print(Factorial(4))
```

Recursive function: behind the scene

A recursive function

```
def Factorial(n):
    if n == 1:
        return 1
    else:
        return n * Factorial(n-1)

print(Factorial(4))
```

When the code is execute:

`Factorial(4)` …

… will call `Factorial(3)`, …

… which will call `Factorial(2)`, …

… which will call `Factorial(1)`, …

… which will return 1

A recursive function must have at least one EXIT CODITION

Can we do it non-recursively?

A non-recursive factorial function

```
def Factorial(n):
    result = 1
    for i in range(2, n + 1):
        result *= i
    return result
```

In fact, any recursive algorithm can be converted to non-recursive form
But in many cases, recursive form is:

- Easier to write
- Easier to understand (and debug)
- More elegant/succinct
- More closely follow the original definition (e.g. from maths, fractals)

But, if not used carefully, they may also consume a lot of memory and computation time

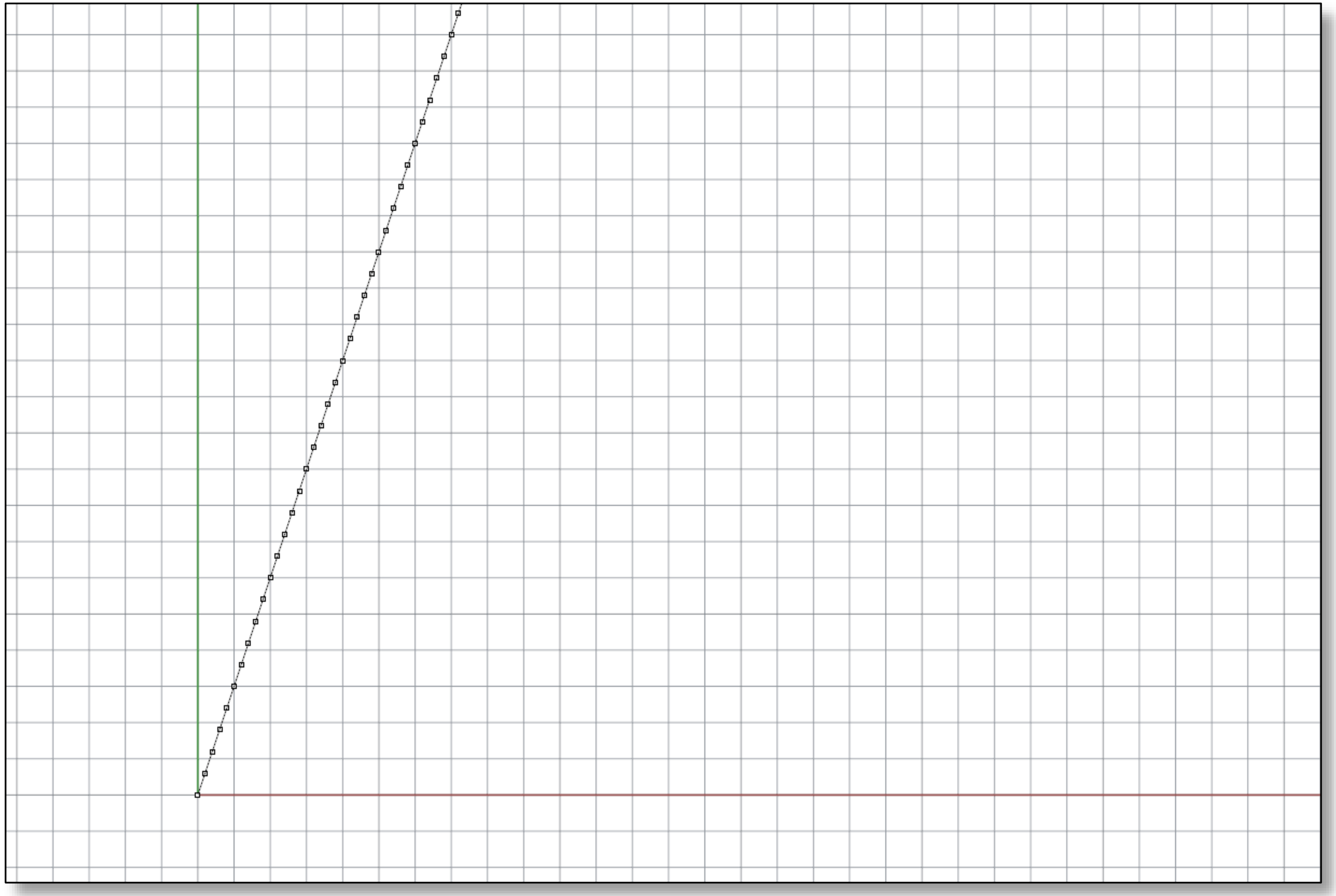
Live Example: Creating Rhino geometry recursively

Step 1: Recursively create (continuous) line segments

```
import rhinoscriptsyntax as rs


def MoveRecursively(startPoint, moveVector, currentStep, maxStep):

    endPoint = rs.VectorAdd(startPoint, moveVector)
    rs.AddLine(startPoint, endPoint)
    rs.AddPoint(startPoint)

    if (currentStep < maxStep):
        MoveRecursively(endPoint, moveVector, currentStep + 1, maxStep)

MoveRecursively( (0, 0, 0), (0.2, 0.6, 0), 0, 100 )
```

Live Example: Creating Rhino geometry recursively

Step 1: Recursively create (continuous) line segments



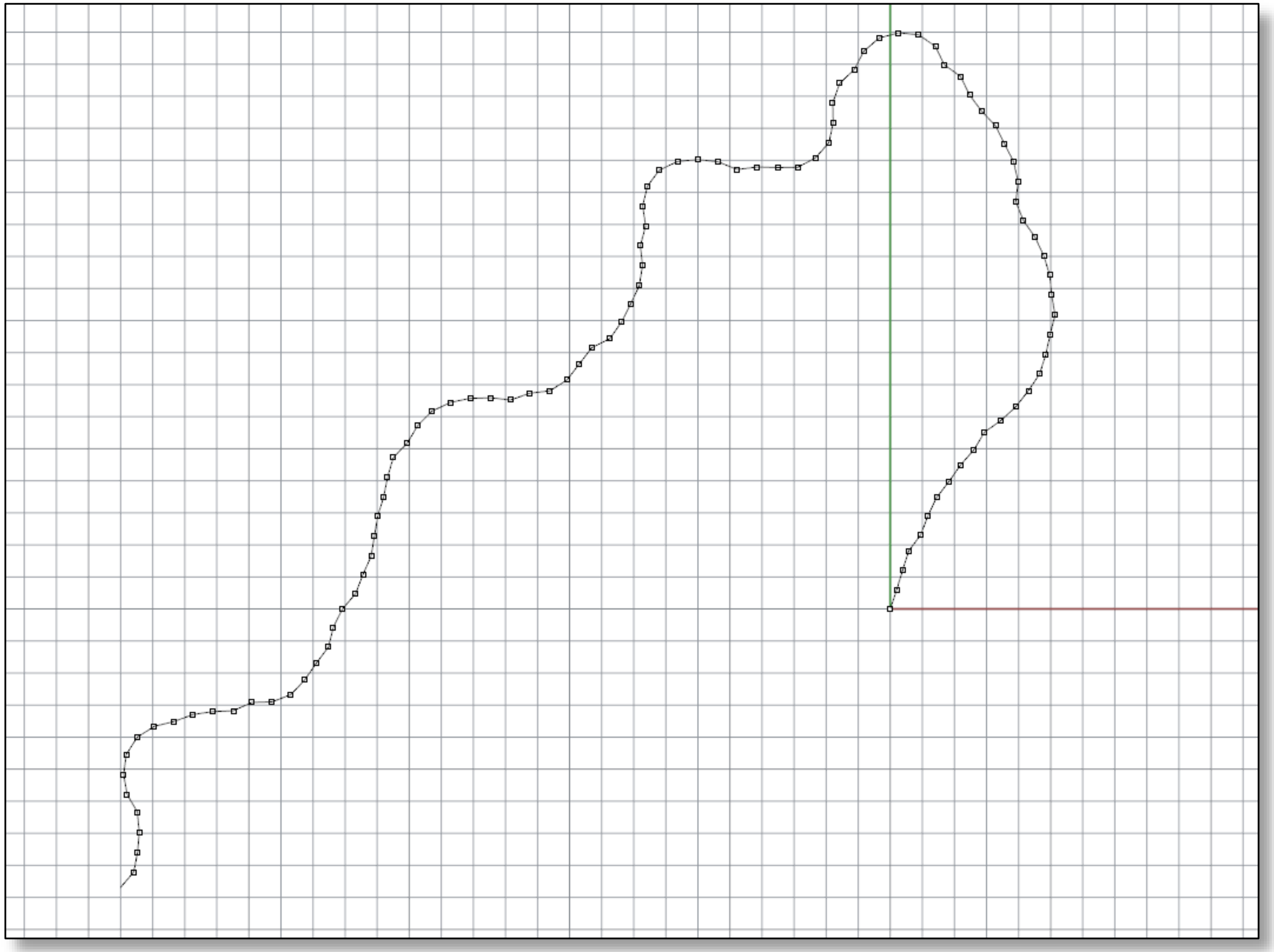
Live Example: Creating Rhino geometry recursively

Step 2: Slightly change the moveVector by a random amount at each step

```
import rhinoscriptsyntax as rs
import random

def MoveRecursively(startPoint, moveVector, currentStep, maxStep):

    endPoint = rs.VectorAdd(startPoint, moveVector)
    rs.AddLine(startPoint, endPoint)
    rs.AddPoint(startPoint)

    if (currentStep < maxStep):
        moveVector = rs.VectorRotate(moveVector, random.uniform(-30, 30), (0, 0, 1))
        MoveRecursively(endPoint, moveVector, currentStep + 1, maxStep)

MoveRecursively( (0, 0, 0), (0.2, 0.6, 0), 0, 100 )
```

Live Example: Creating Rhino geometry recursively

Step 2: Slightly change the moveVector by a random amount at each step



A typical pattern for writing recursive function

```
def MyRecursiveFunction(inputData)

    # Do something useful with inputData (e.g. draw geometries)
    ...

    # compute the input data for the next/recursive call
    nextInputData = ...

    # Make the recursive call
    MyRecursiveFunction(nextInputData)

    # extra computation, if there is any
    ...
```

Recursion

with branching

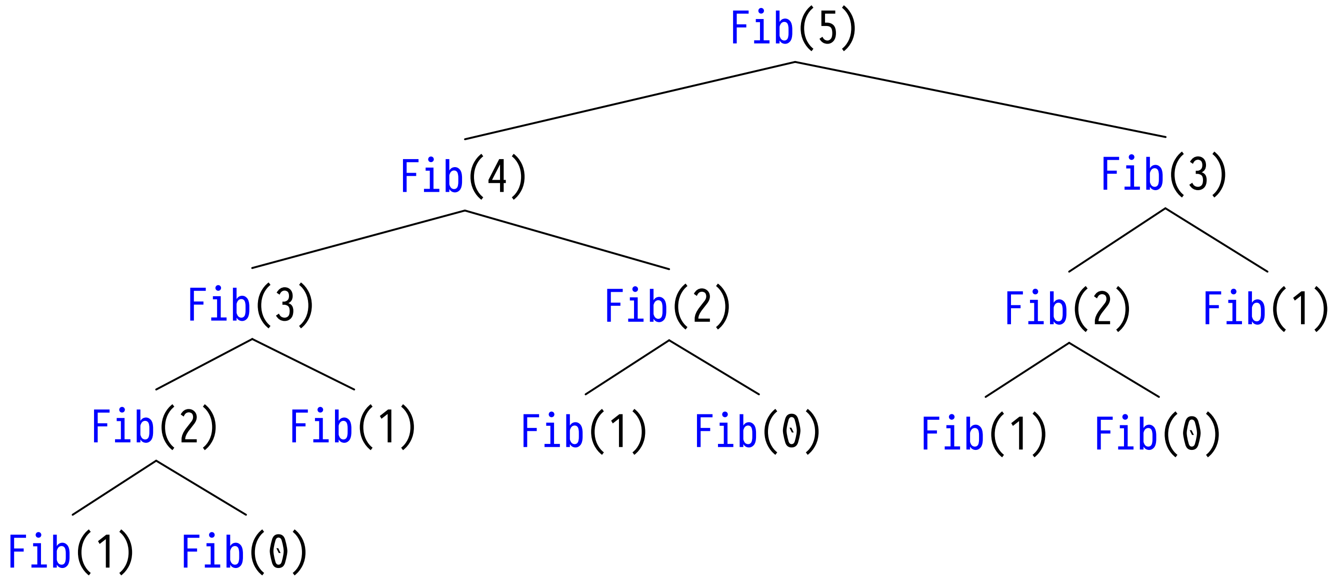
Branching recursion

A function can call itself more than once

The Fibonaci number sequence: 0 1 1 2 3 5 8 13 21 …

Recursive Fibonaci function

```python
def Fib(n):
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        return Fib(n-1) + Fib(n-2)

print(Fib(4))
```



Computation time is proportional to 2^n

Branching recursion

Watchout for exponential growth !!!

Computing the 52^th^ term in the sequence will require 2^{50} recursive calls to the Fib function

Even if each call takes only 1 nanosecond to compute, the total time will be 13 days

Similarly the 66^th^ term will take almost 300 years

… and the 99^th^ term will take 19 billion years !!!

A non-recursive version

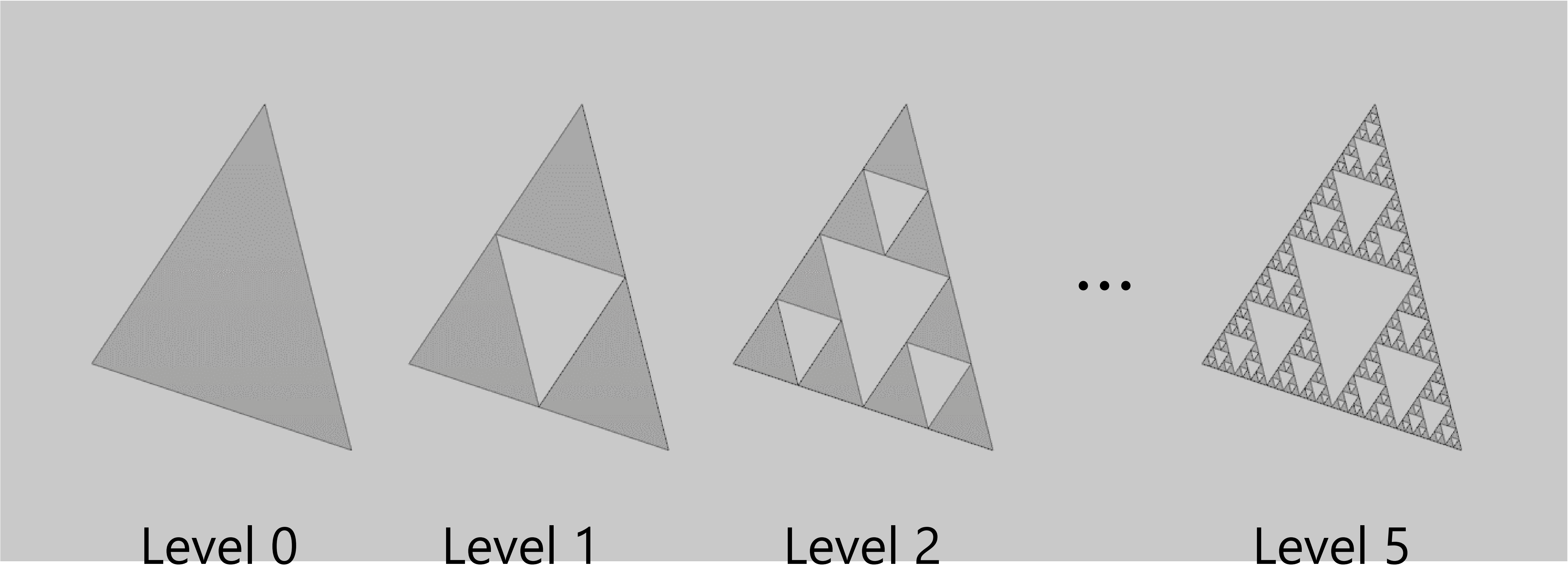
Non-Recursive Fibonaci function

```
def Fib(n):
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        previous = 0
        current = 1
        for i in range(1, n):
            next = current + previous
            previous = current
            current = next
        return current
```

Computation time is proportional to n

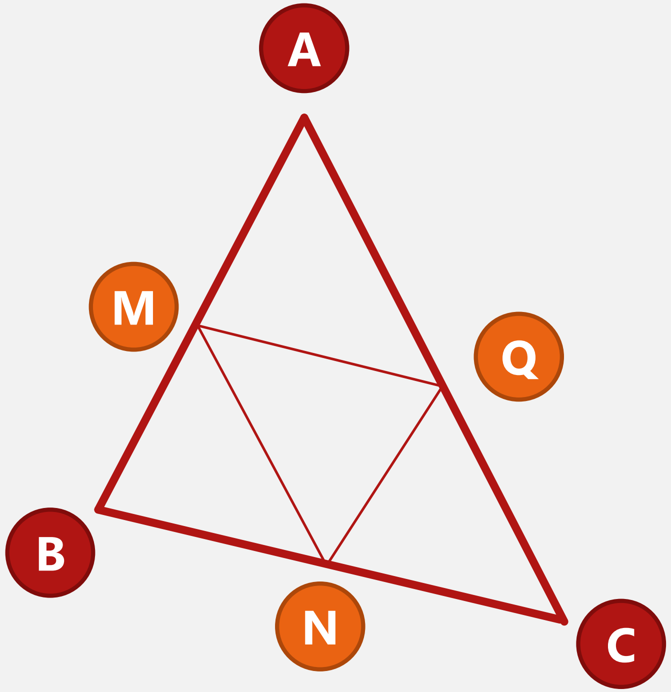
Fractal Geometries

Live Example: Sierpenski triangle



Live Example: Sierpenski triangle

```
import Rhino.Geometry as rg

mesh = rg.Mesh()

def SubdivideTriangle(A, B, C, levelRemained):
    if levelRemained == 0:
        mesh.Vertices.Add(A)
        mesh.Vertices.Add(B)
        mesh.Vertices.Add(C)
        f = mesh.Vertices.Count
        mesh.Faces.AddFace(f-3, f-2, f-1)
    else:
        M = 0.5 * (A + B)
        N = 0.5 * (B + C)
        Q = 0.5 * (C + A)
        SubdivideTriangle(A, M, Q, levelRemained - 1)
        SubdivideTriangle(M, B, N, levelRemained - 1)
        SubdivideTriangle(Q, N, C, levelRemained - 1)

SubdivideTriangle(rg.Point3d(2,4,0), rg.Point3d(0,1,0),
                  rg.Point3d(3,0,0), 5 )
```



A recursive joke from Google

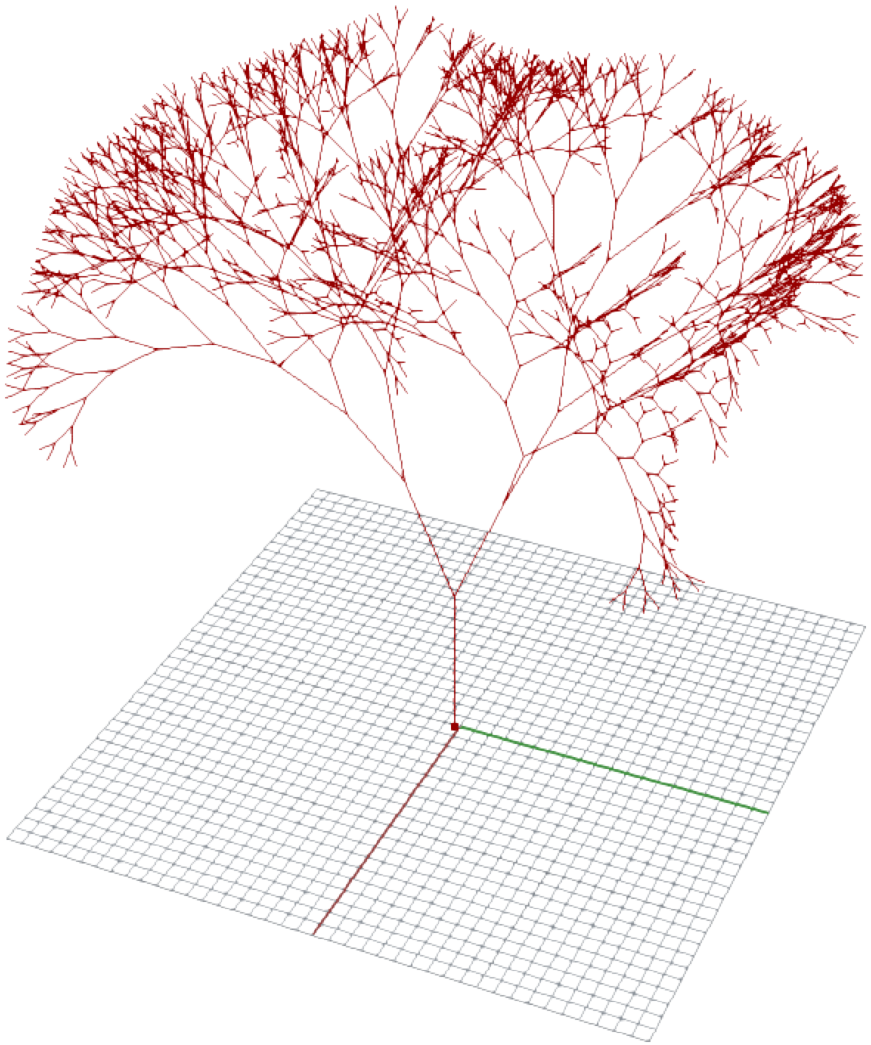
Live Example: Tree growth

L-System invented by Lindenmayer (1968)

- A formal way to describe the growth of tree
- Based on the so-called “parallel rewriting system”: essentially a set of recursive rules, optionally with adjustable parameters and some randomness
- Can realistically generate the shape (morphology) of many trees/plants

Live Example: Tree growth

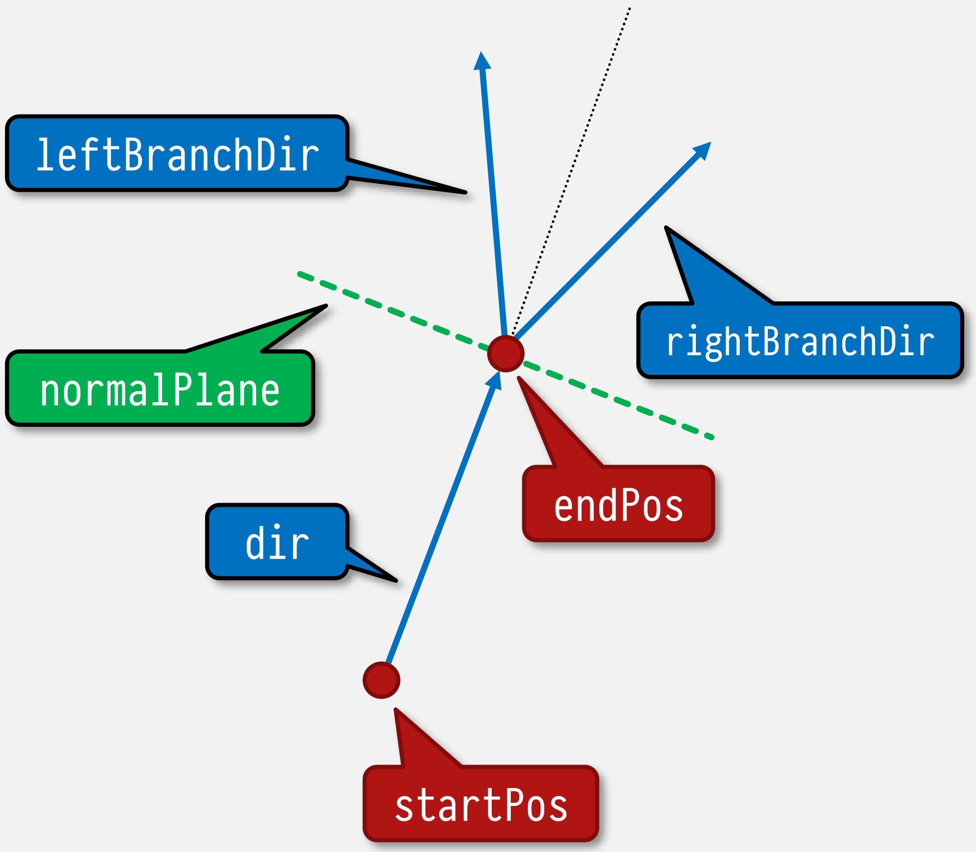
Step 1: Defining a branching recursive function



Live Example: Tree growth

Step 1: Defining a branching recursive function

```
import Rhino.Geometry as rg

branches = []

def Branch(startPos, dir, levelRemained):
    endPos = startPos + dir
    branches.append(rg.Line(startPos, endPos))

    if (levelRemained > 0):
        normalPlane = rg.Plane(endPos, dir)

        leftBranchDir = rg.Vector3d(dir)
        leftBranchDir.Rotate(-iSpreadAngle, normalPlane.XAxis)
        leftBranchDir *= iShrink
        Branch(endPos, leftBranchDir, levelRemained - 1)

        rightBranchDir = rg.Vector3d(dir)
        rightBranchDir.Rotate(iSpreadAngle, normalPlane.XAxis)
        rightBranchDir *= iShrink
        Branch(endPos, rightBranchDir, levelRemained - 1)

Branch(iRootPosition, iRootDirection, 10)
```



Live Example: Tree growth

Step 2: Adding a random twist to the normal plane

```
def Branch(startPos, dir, levelRemained):
    ...
    if (levelRemained > 0):
        normalPlane = rg.Plane(endPos, dir)
        normalPlane = rg.Rotate(random.uniform(0, 3.14), normalPlane.ZAxis)
        ...
```

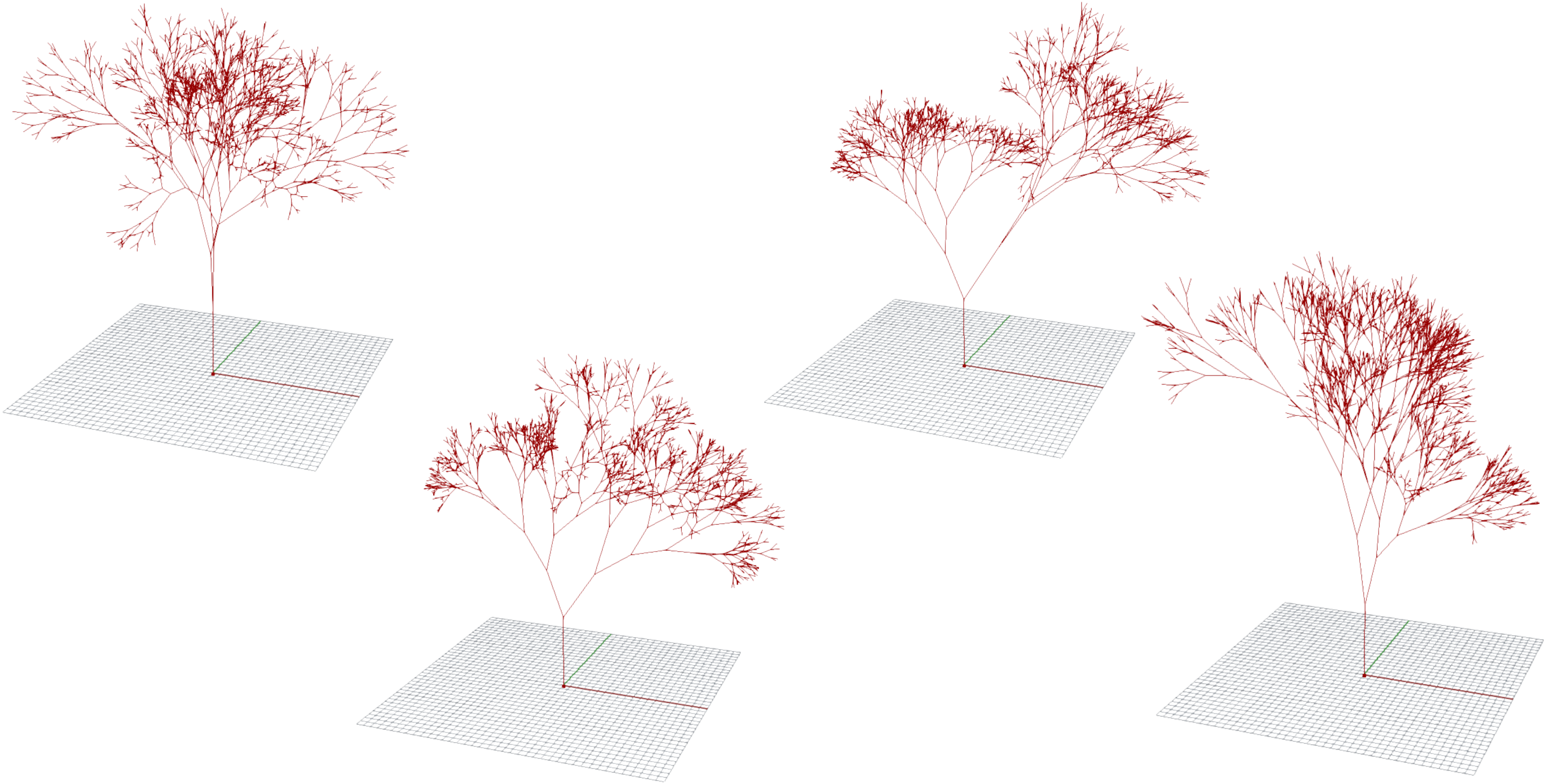
Live Example: Tree growth

Step 3: Adding random variations to the spread angles and shrink factor

```
import Rhino.Geometry as rg
import random

branches = []

def Branch(startPos, dir, levelRemained):
    ...

    if (levelRemained > 0):
        ...

        leftBranchDir = rg.Vector3d(dir)
        leftBranchDir.Rotate(-iSpreadAngle + random.uniform(0, iSpreadVariation), normalPlane.XAxis)
        leftBranchDir *= iShrink + random.uniform(0, iShrinkVariation)
        Branch(endPos, leftBranchDir, levelRemained - 1)

        rightBranchDir = rg.Vector3d(dir)
        rightBranchDir.Rotate(iSpreadAngle + random.uniform(0, iSpreadVariation), normalPlane.XAxis)
        rightBranchDir *= iShrink + random.uniform(0, iShrinkVariation)
        Branch(endPos, rightBranchDir, levelRemained - 1)

Branch(iRootPosition, iRootDirection, 10)
```

Live Example: Tree growth

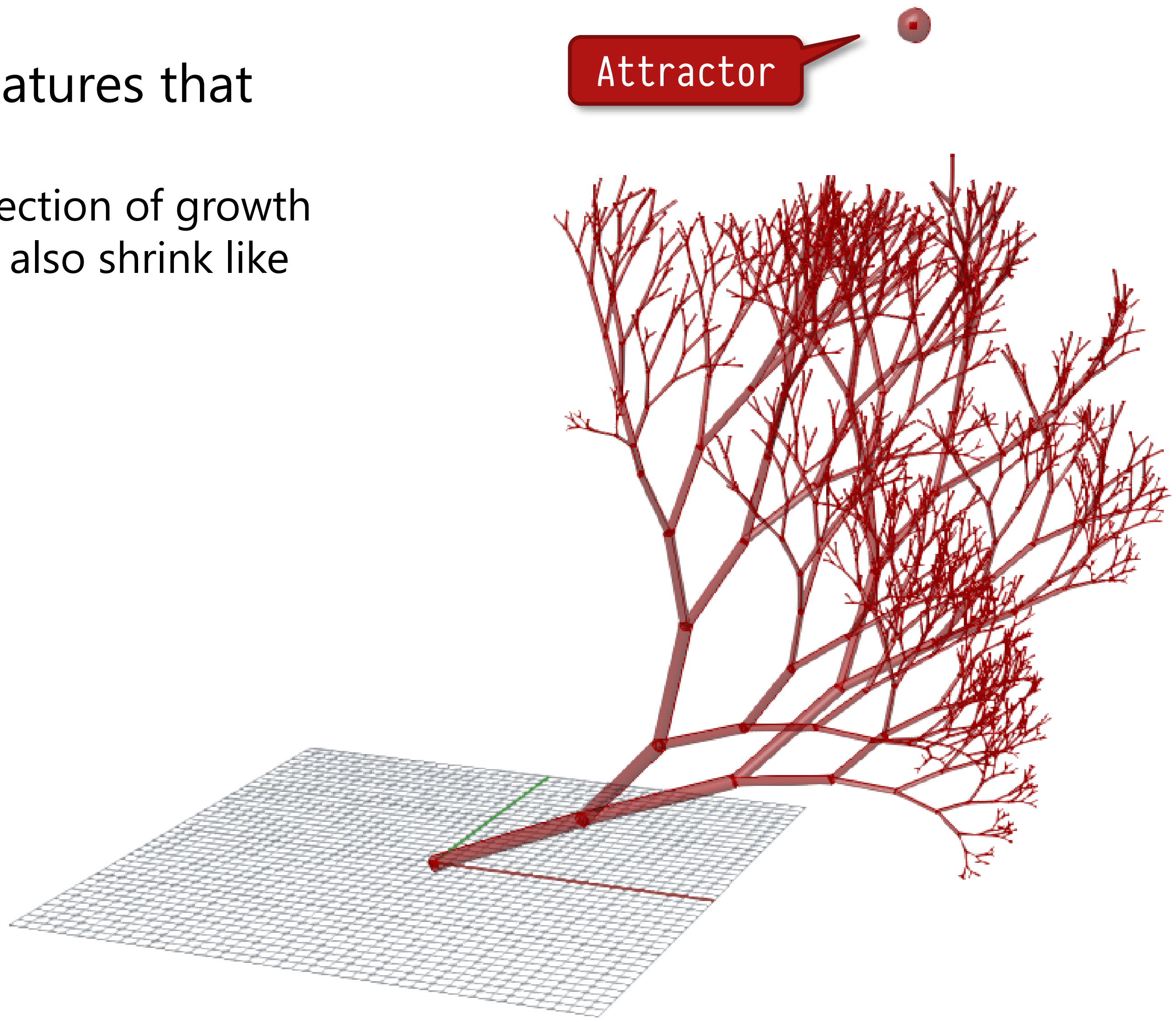
Step 3: Adding random variations to the spread angle and shrink factor



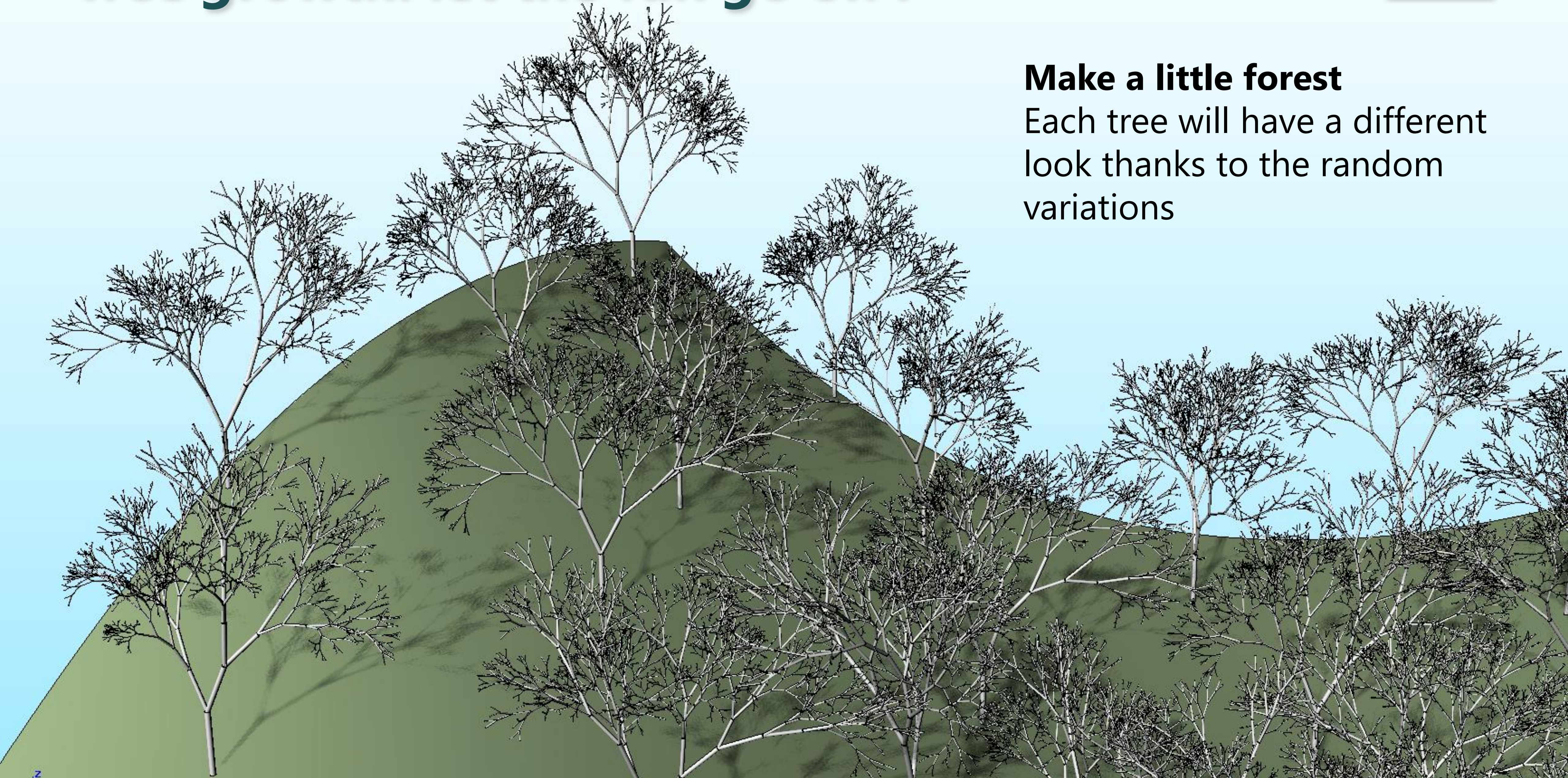
Tree growth: let the fun go on !

There are so many interesting features that you can add:

- Attractor point that influence the direction of growth
- Branches with thickness (that should also shrink like the branch length)



Tree growth: let the fun go on !



Make a little forest

Each tree will have a different look thanks to the random variations