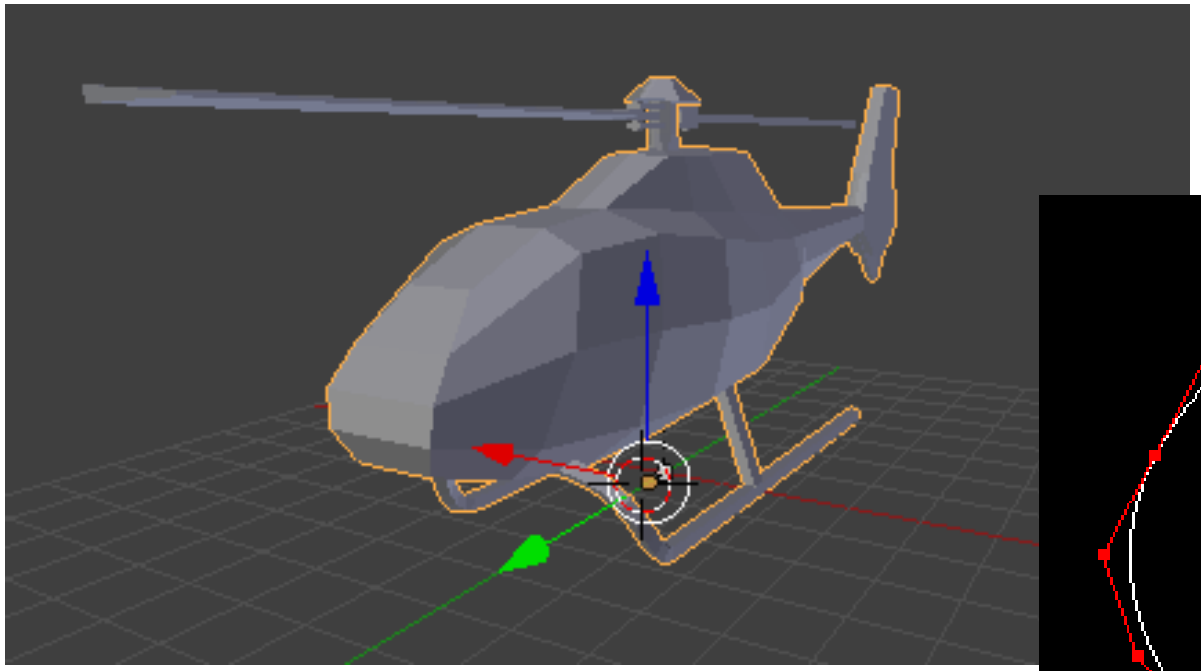
Computer Graphics

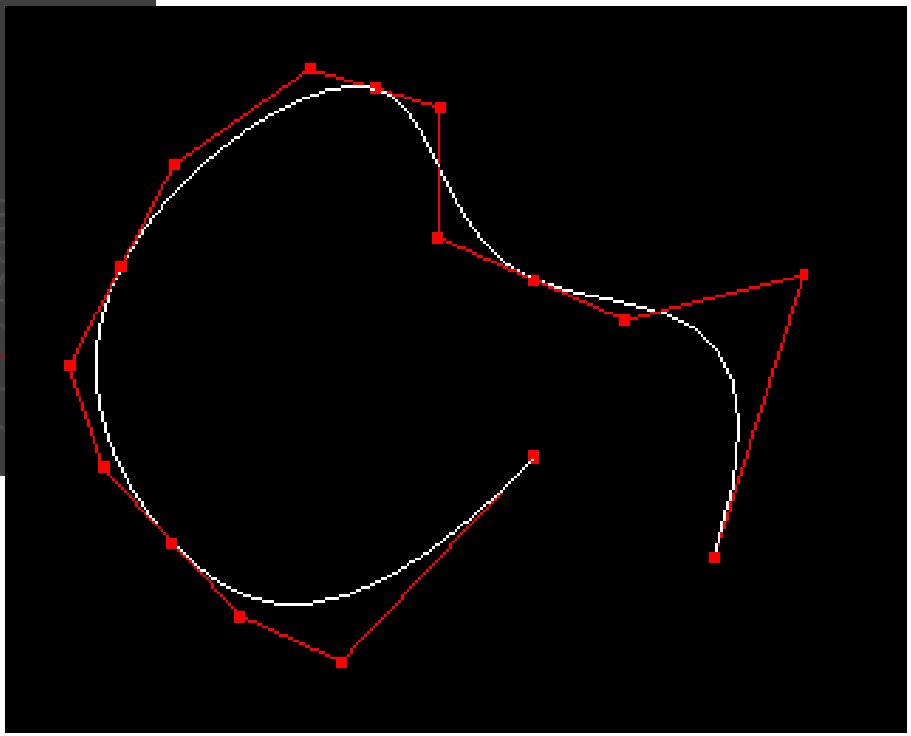
MTAT.03.015

Raimond Tunnel

Study IT in .ee

The Road So Far...





```
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o Plane
v 1.007839 0.000000 -1.000000
v 1.000000 0.000000 0.978599
v -1.000000 0.000000 -0.588960
usemtl None
s off
f 3 2 1
```

Procedural Generation

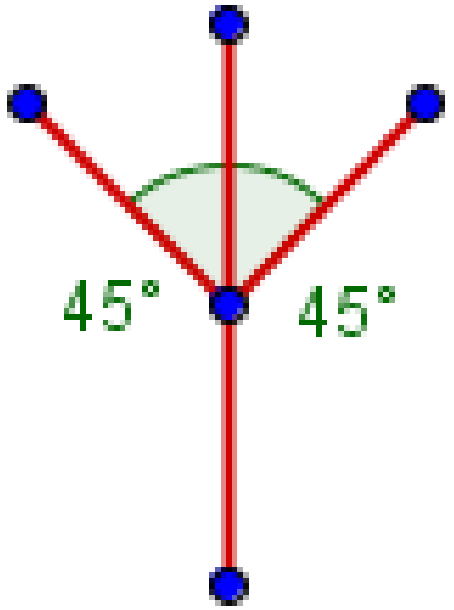
- Generating objects algorithmically
  - Mesh (geometry)
  - Material (texture)
  - Effects (particles)
  - Animation
  - Worlds
  - Characters, weapons, space ships, ...
- More different content, less work for artists

Tree

- Let's try to generate a tree branch structure.
- We start with a trunk.

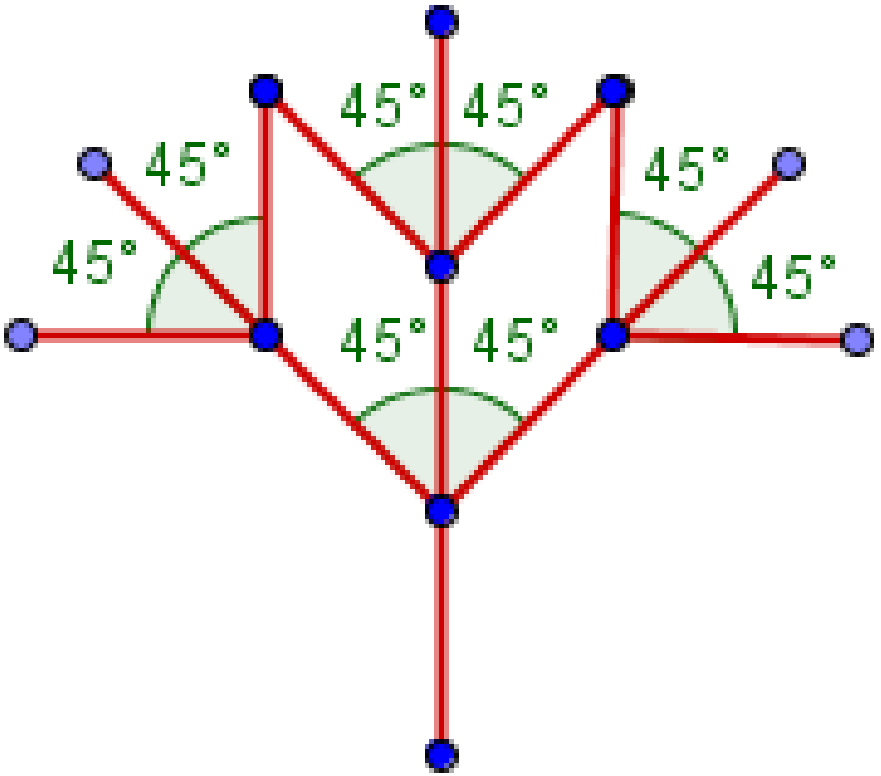
Tree

- From the trunk, we create two branches for either side.
- We also continue on the forward path.



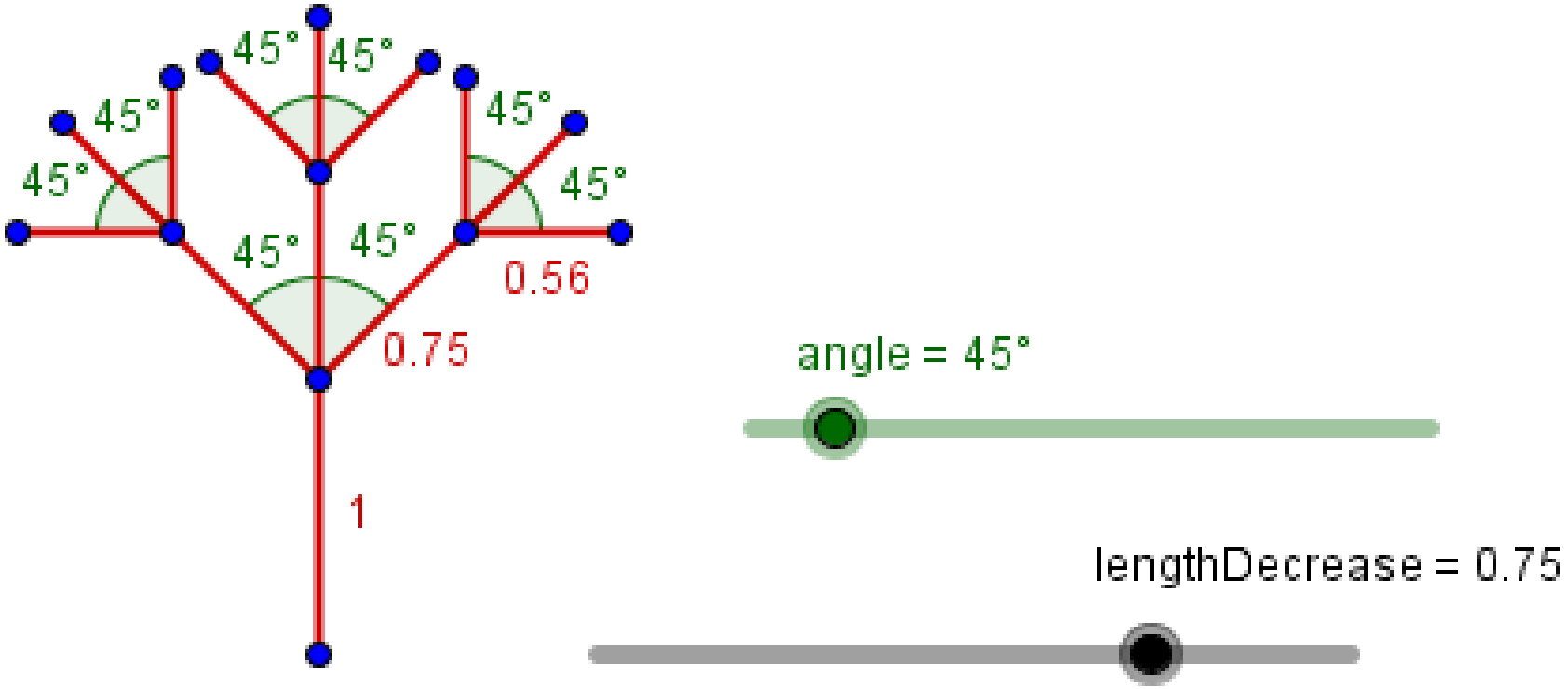
Tree

- We repeat the same process for all of the new segments.



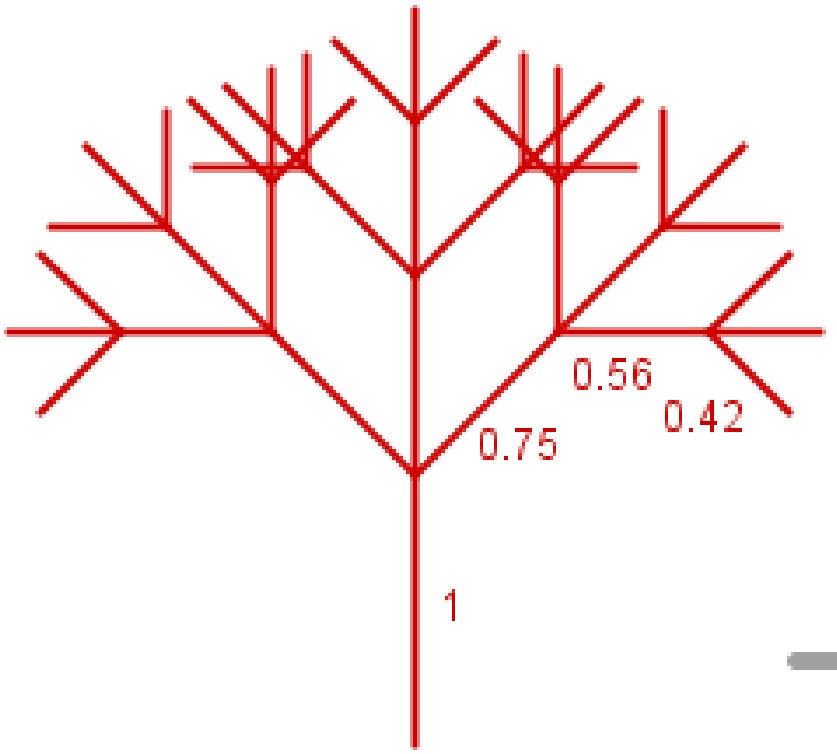
Tree

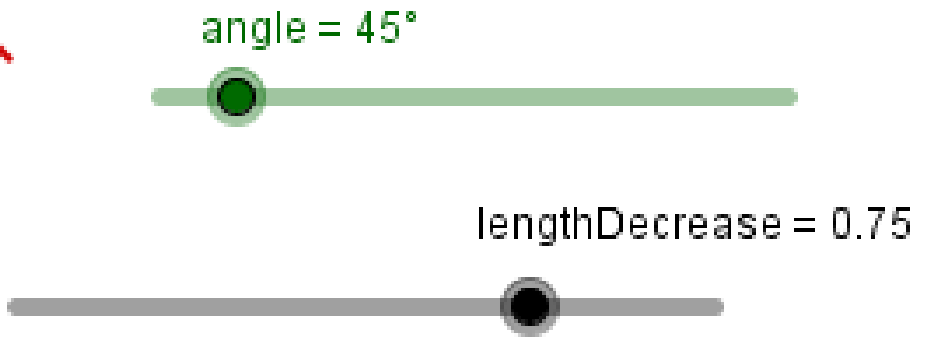
- Decrease the length of the segments each time.



Tree

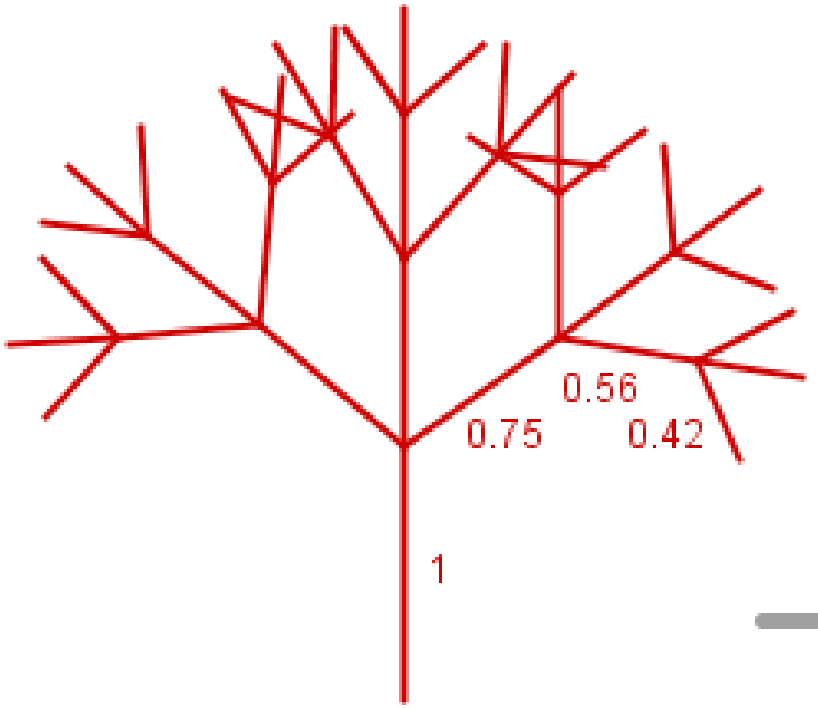
- Repeat again the same process.

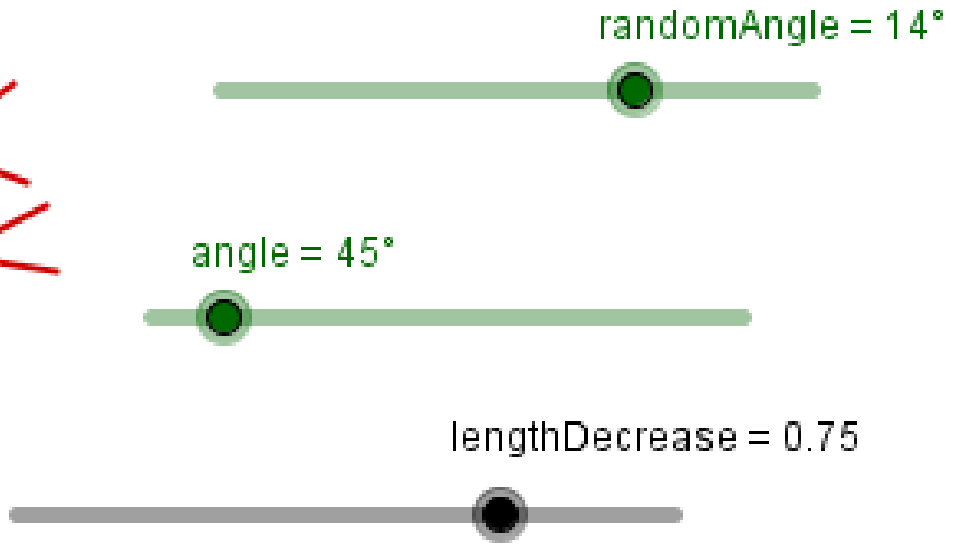




Tree

- Introduce randomness.

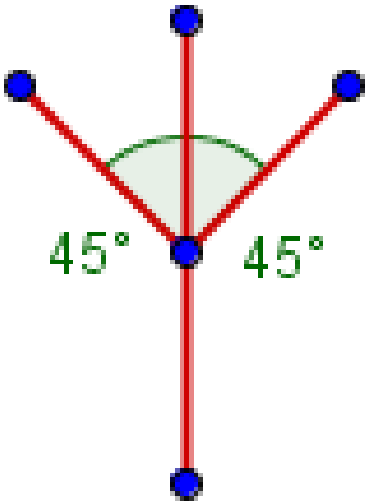


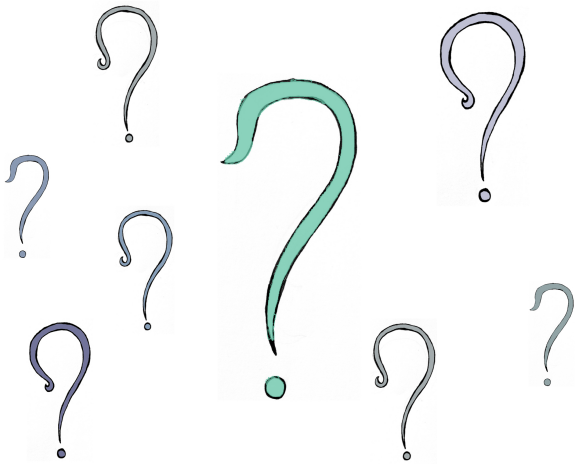


Show this in action...

Tree

- What if we want to store the generated tree structure?
- For example, this smaller tree:
- We should specify the strucutre and the parameters (length, angle).





Formal Grammar (Chomsky)

- Formal grammar consists of:
  - Set of nonterminal symbols N.
  - Set of terminal symbols Σ .
  - Set of production rules.
  - Starting axiom.
- Example:

$N = \{A\}$ $\quad Axiom = A$

$\Sigma = \{a\}$

$R = \begin{Bmatrix} A \rightarrow AA \\ A \rightarrow a \end{Bmatrix}$

Generates words

$A \rightarrow a$

$A \rightarrow AA \rightarrow aA \rightarrow aa$

$A \rightarrow AA \rightarrow AAA \rightarrow aAA \rightarrow aaA \rightarrow aaa$

...

Formal Grammar (Chomsky)

- Used for:
  - Natural language processing
  - Program code processing (compiler, interpreter)
- Hierarchy of types
  - **Type 0: Unrestricted** – $N = \Sigma$
  - **Type 1: Context sensitive** – non-terminal symbol on the left side, can be surrounded by a context
  - **Type 2: Context free** – left side contains only a single non-terminal symbol
  - **Type 3: Regular** – right side is empty, single terminal, or single terminal follower by non-terminal

Lindenmayer System

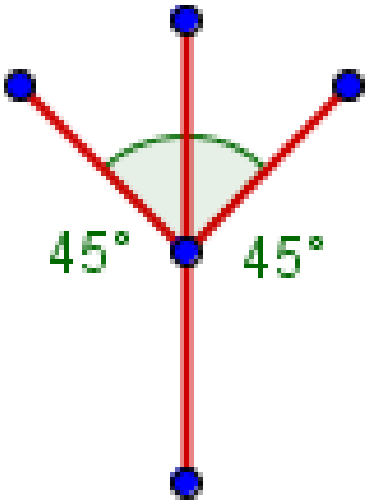
- **Variant of a formal grammar.**
- **Parallel rewriting system.**
- We will look at one, that is:
  - Bracketed system.
  - Stochastic system.
  - Context free (0L-system).
  - Parametric system.

Because of that, does not fall directly under Chomsky's hierarcy

Lindenmayer System

- **Bracketed system** – we use brackets to indicate branches.
- Let's use such symbols:

Symbol	Meaning
F	Segment
+	Rotate left 45°
-	Rotate right 45°
[	Start of a branch
]	End of a branch



Can we write our tree using those?

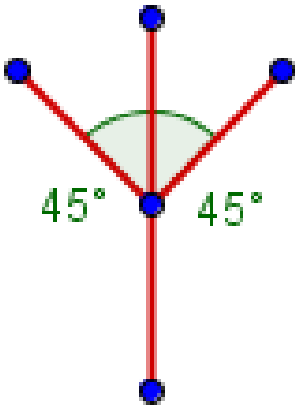
Lindenmayer System

- **Parallel rewriting system** – we can specify rules to generate the tree.
  - Start from the axiom.
  - Rewrite (apply rules) to all symbols at once.

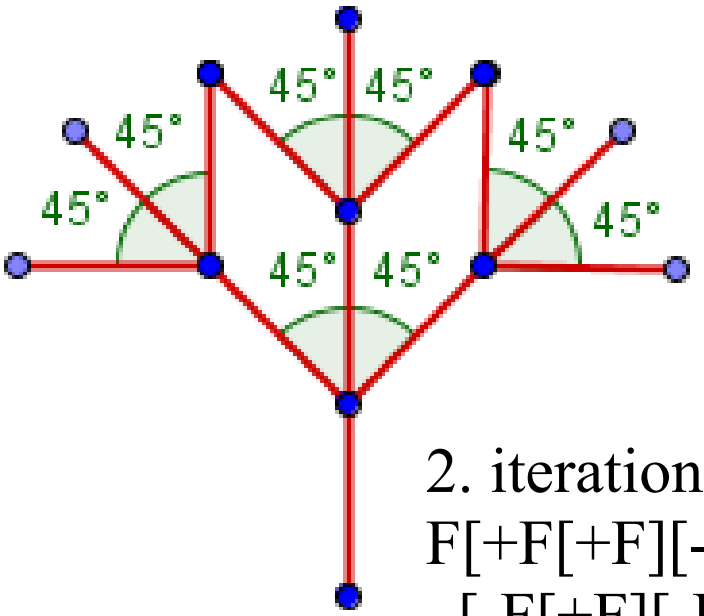
What would be the rules?

This is a trick question.

Axiom: F



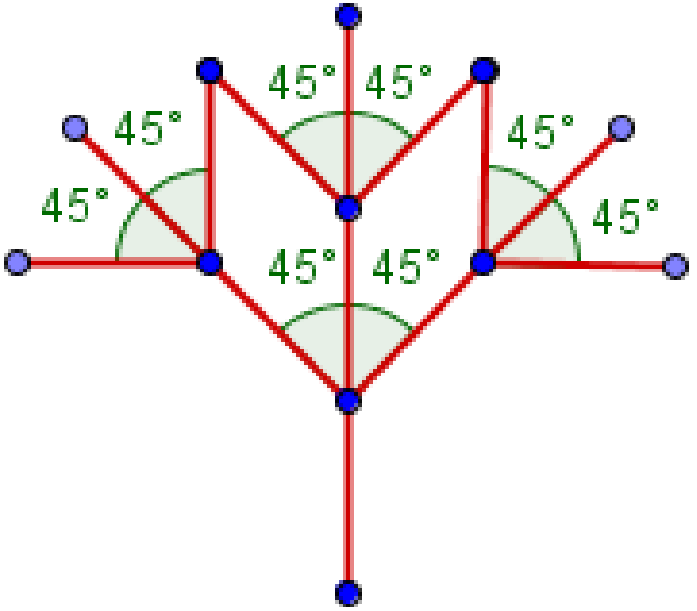
1. iteration: F[+F][-F]F



2. iteration:
F[+F[+F][-F]F]
[-F[+F][-F]F]
F[+F][-F]F

Lindenmayer System

- **Parametric system** – we can specify parameters for the symbols.
  - The length, the angle etc

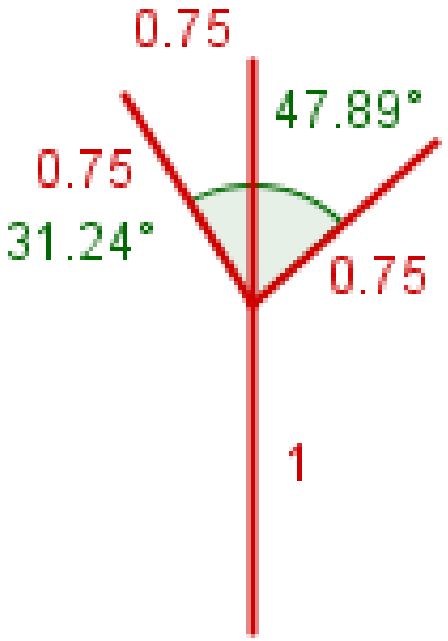


F[+(45)F[+(45)F][-(45)F]F]
[-(45)F[+(45)F][-(45)F]F]
F[+(45)F][-(45)F]F

Every + or - is followed by the angle of rotation.

Lindenmayer System

- We can generate angles with some variance.
- Also specify the lengths of the segments.



If the decrease of lengths is deterministic, we could consider it only, when drawing the tree...

F(1)[+(31.24)F(0.75)][-(47.89)F(0.75)]F(0.75)

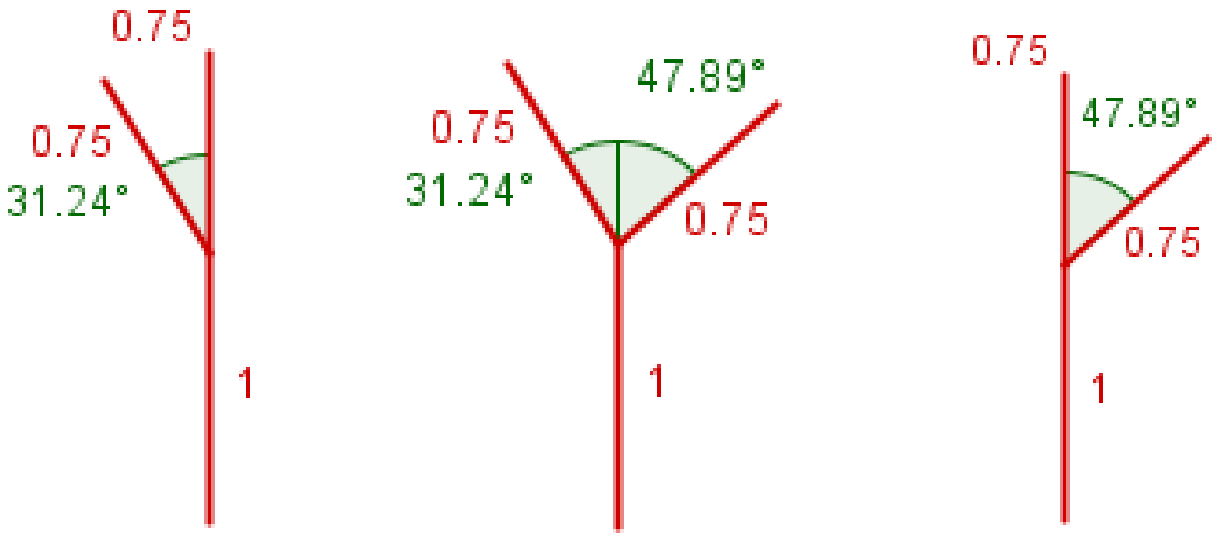
Lindenmayer System

- **Stochastic system** – we can have many rules, with the same left-hand side.
- Each rule has a probability.
- The sum of the probabilities of all the rules, with the same left-hand side, has to be 1.

$$A \xrightarrow{1/3} F[+A]A$$

$$A \xrightarrow{1/3} F[-A]A$$

$$A \xrightarrow{1/3} F[+A][-A]$$



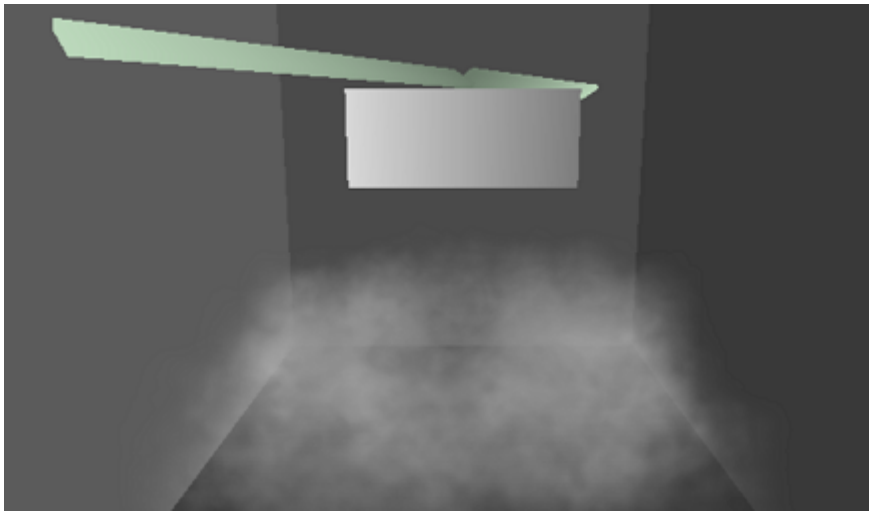
Lindenmayer System

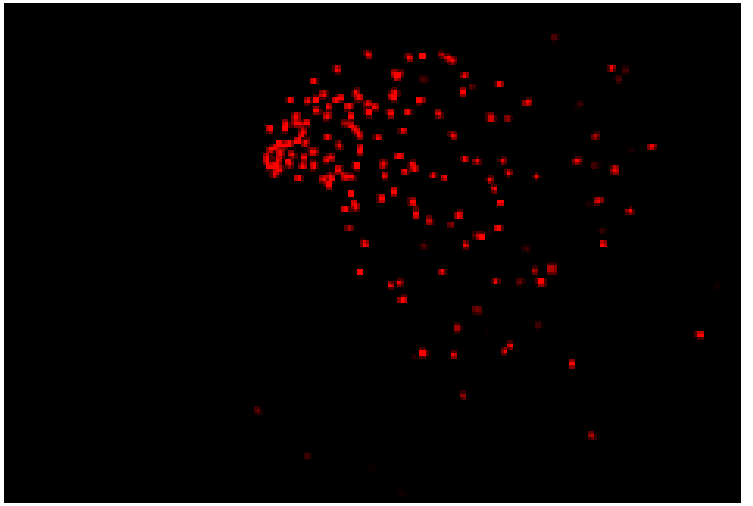
- Rigorous way to specify a mechanism for a **self-similar** structure generation.
- Lot of research and different possibilities.
- *The Algorithmic Beauty of Plants*, A. Lindenmayer, P. Prusinkiewicz. http://algorithmicbotany.org/papers/abop/abop.pdf
- Interesting plugin for Unity: http://forum.unity3d.com/threads/l-systems-for-unity-free-script-included.272416/
- Questions?

Particle System

- Used for different effects
  - Fire, fluid, wind, smoke
  - Precipitation (rain, snow)
  - Groups of objects with behaviour (birds, NPC-s)

This you did in the Soft Particle Chopper.

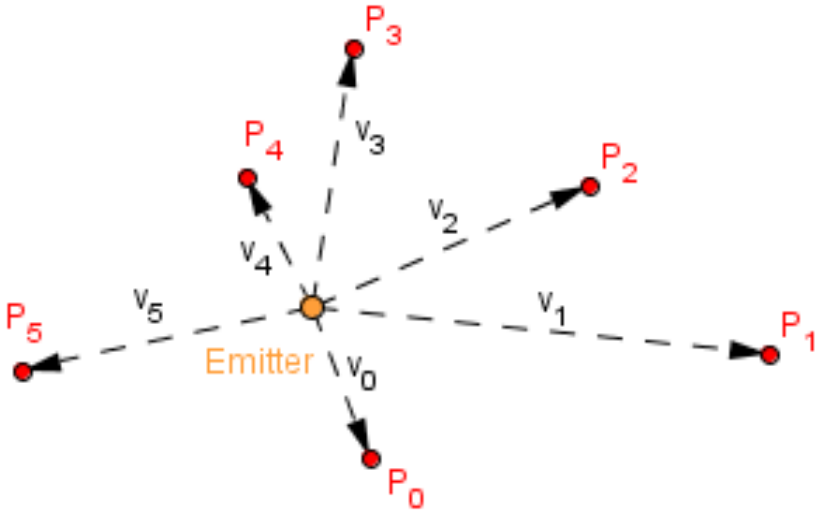




Particle System

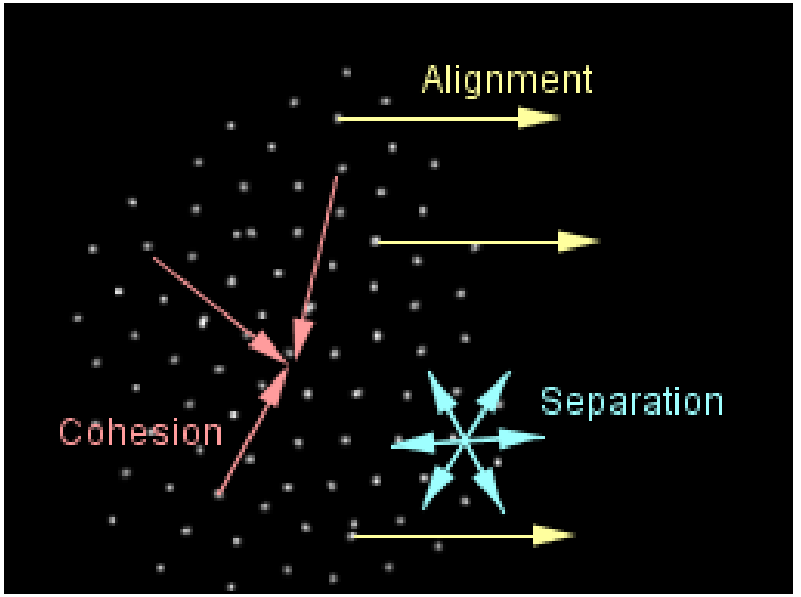
- Particles can have a transparency that varies over time.
- Particles can be generated from a pool.
  - If a particle dies, return it to the pool.
- Particle can be 1 pixel in size, or have an image.
- Particle system has an emmitter of particles.

Emitter can also be a line,
a surface, a volume etc.



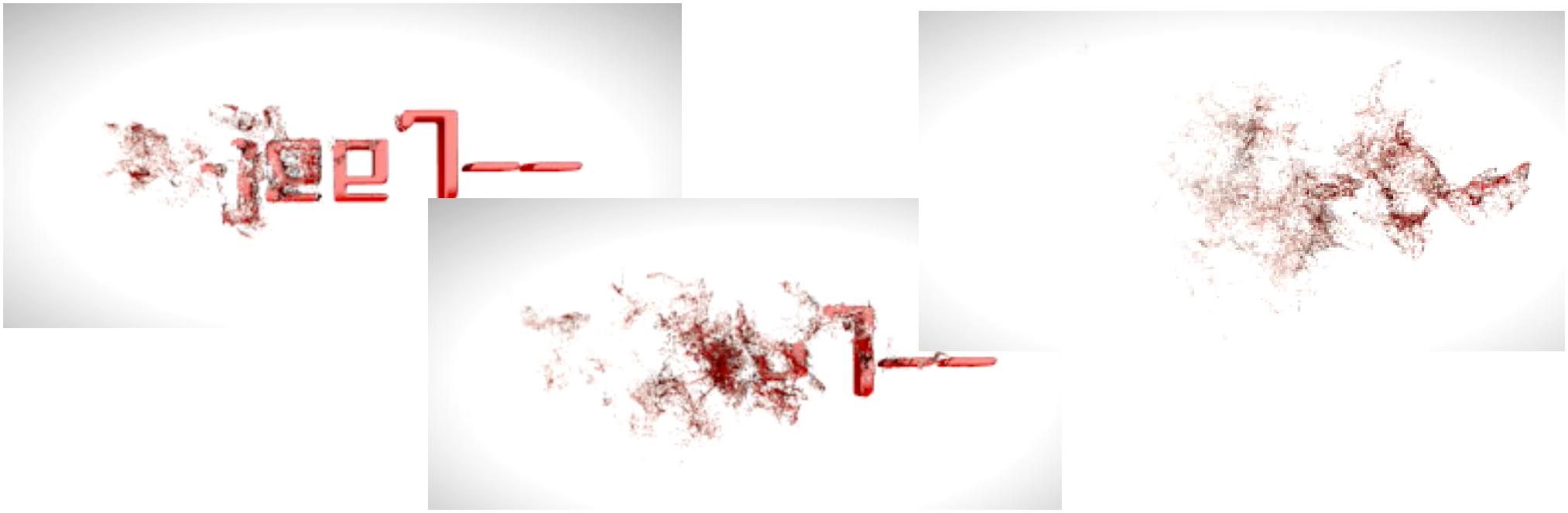
Boids Algorithm

- Used to model flocking (of birds).
- Each particle follows a set of rules:
  - **Cohesion** – Move towards the center of mass.
  - **Separation** – Keep distance from other particles.
  - **Alignment** – Follow the average direction.
- There can be other rules.



Particle Systems

- Blender has particle systems



- Example of scar generation via particles: https://www.allegorithmic.com/community/blog/creative-use-particle-brushes

What did you learn today?

What more would you like to know?

Next time: Ray Casting, Ray Tracing, Space Partitioning, BVH