

Procedural City Generation with Shape Grammar

Jozef Janosko

Intro to Shape Geometry: Formal Grammars and L-systems

Formal Grammar : an abstract structure that describes a language specifically, and consisting of a finite alphabet and a finite set of rules which can be used to generate all possible strings (Vrajitoru)

- Often used to write compilers
- Used in Natural Language Processing

L-system : a type of grammar which formally defines the shape of an object using recursive rewriting and a formal grammar (University of Texas at Austin)

- Invented by a botanist and originally used to model plants
- Consists of Axioms (an initial shape), Variables (a set of shapes which can be used in rewriting), Terminals (shapes which are not rewritten), and Rules

L-System: Koch Curve

Rule:

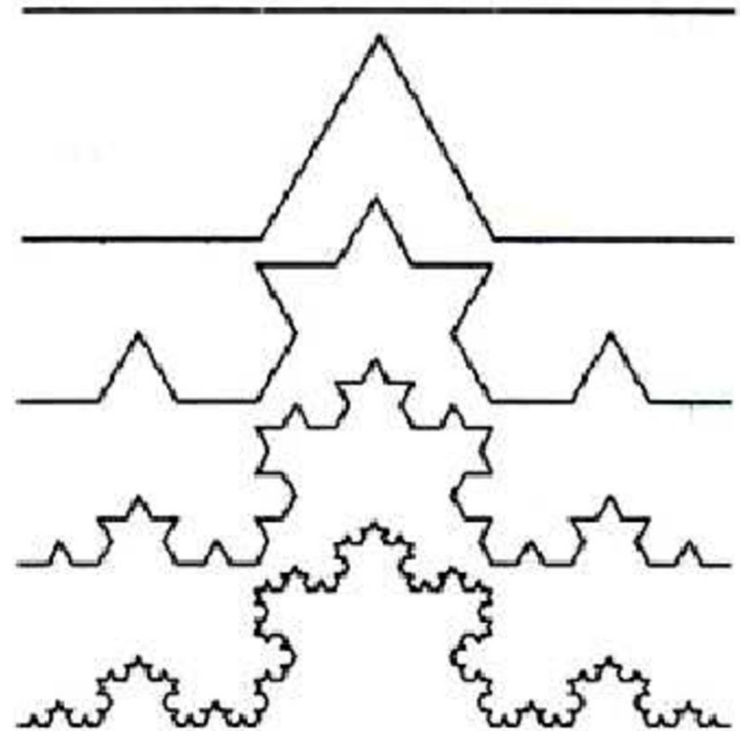
$F = F - F ++ F - F$

Variables:

F = line segment (scaled to $\frac{1}{3}$) (axiom)

$-$ = turn 60 degrees counterclockwise

$+$ = turn 60 degrees clockwise



Shape Grammars:

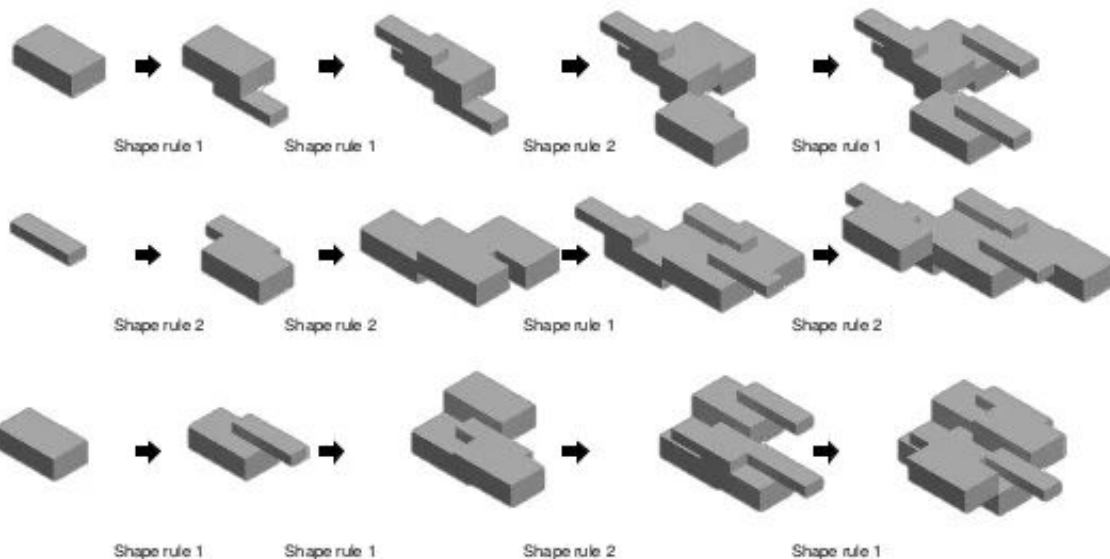
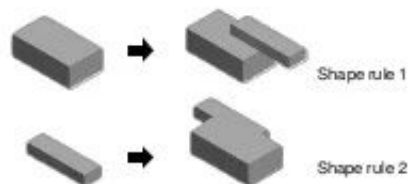
Consists of Symbols (terminal and non-terminal), Shapes (geometric objects mapped to symbols with numerical data), and Rules.

Shapes are added to a model based on the the set of symbols in the current string, symbols are added based on the rule, just as in L-systems.

The End result is a complex network of shapes which is ordered by a set of rules, but can look natural and chaotic.

Exercise 4

Two rules 3D shape grammar



Application of Shape Grammar to Cities

Buildings are made up of fundamental units (boxes, pyramids, prisms).

A building can be procedurally designed using Shape Grammar.

Generate lots of shapes, place them near each other - you have a city!



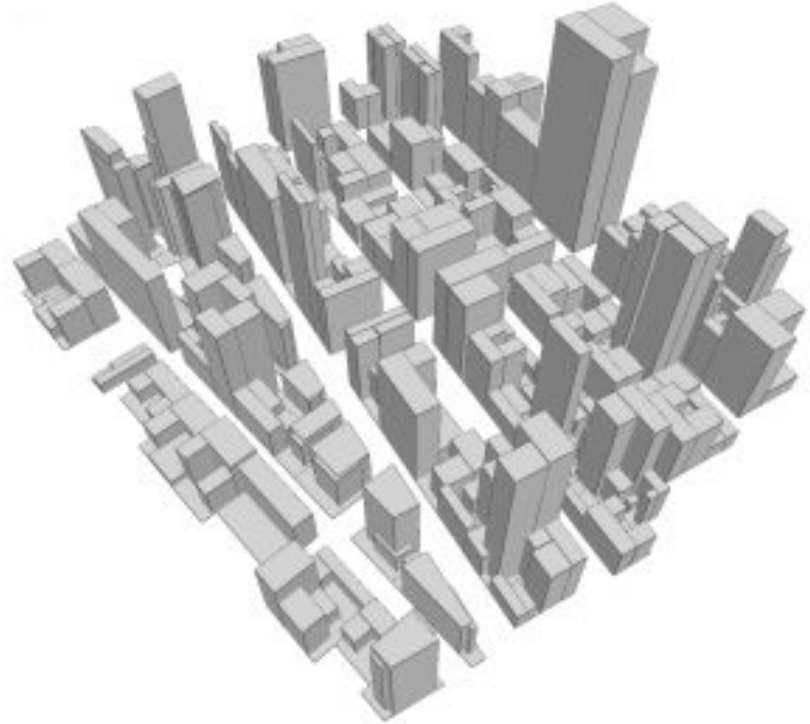
Extra Considerations

Shapes and Rules must be designed with collisions and intersection in mind

Extra bounds such as Roads, Rivers, etc may be desired and must be handled

Cities (building placement) vary in density

Lots may be mapped to a complex terrain



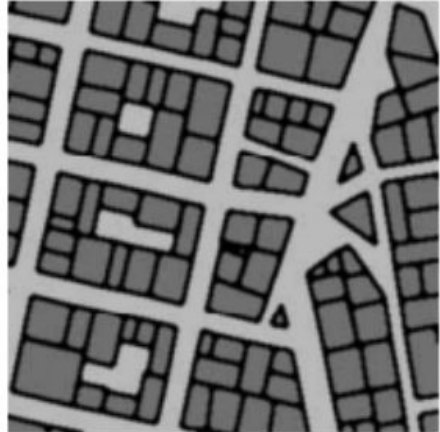
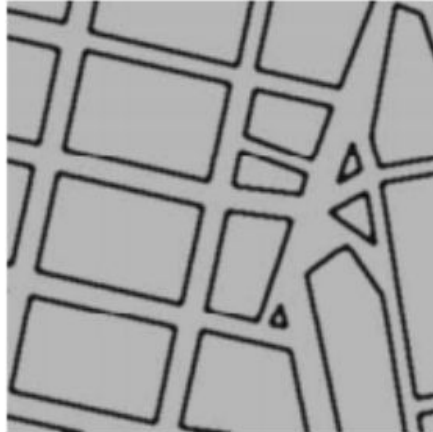
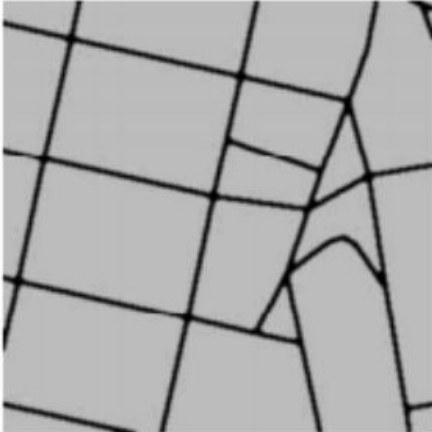
General Approach

Generate terrain

Generate grammar based roads over the terrain, dividing space into blocks

Subdivide blocks into individual lots for each building

Use shape grammar to generate a building that fits into the lot.



Examples from CityEngine



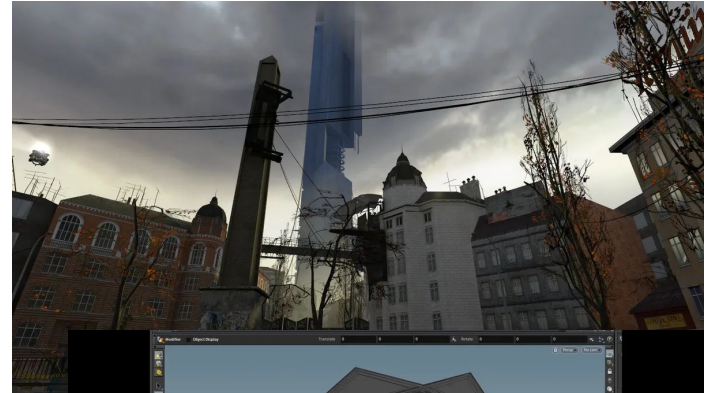
Applications for Procedural Cities

Movies

Video Games

Architecture / City Planning

Because it looks cool



Road Placement Using an L-system/Shape Grammar

Extra Considerations:

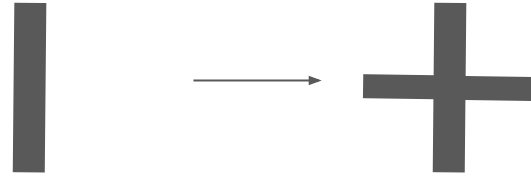
Roads which branch from the axiom road must become smaller in both length and width.

Randomizing branching roads makes for more “natural” look.

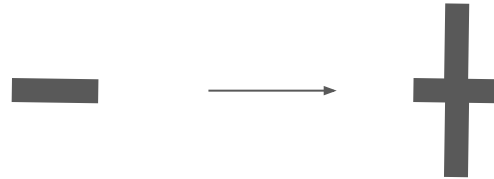
Shapes: Vertical and Horizontal Lines

Rules:

1.



2.



Works Cited

- Arcgis.com. (n.d.). Retrieved December 6, 2022, from <https://www.arcgis.com/home/group.html?id=01695af30a384c1e823fa4d72497309d#overview>
- Hwang, R. (n.d.). *Project 4: Shape grammar*. cis700. Retrieved December 6, 2022, from <https://cis700-procedural-graphics.github.io/assignments/proj4-shape-grammar/>
- Mueller, P., Wonka, P., Haelger, S., Ulmer, A., & Gool, L. V. (n.d.). *Procedural Modeling of Buildings*. Retrieved December 6, 2022, from <http://www.peterwonka.net/Publications/pdfs/2006.SG.Mueller.ProceduralModelingOfBuildings.final.pdf>
- University of Texas at Austin. (n.d.). *L-Systems and Particle Systems*. CS354 Computer Graphics. Retrieved December 6, 2022, from <https://www.cs.utexas.edu/~theshark/courses/cs354/lectures/cs354-22.pdf>
- Vrajitoru, D. (n.d.). *Introduction to Formal Grammars*. C311 introduction to formal grammars. Retrieved December 6, 2022, from https://www.cs.iusb.edu/~danav/teach/c311/c311_9_grammars.html