Comp 763 – Modeling and Simulation Based Design Presentation
March 17th, 2008

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PROCEDURAL TECHNIQUES FOR CITY GENERATION

Reference

George Kelly, Hugh McCabe. *A Survey of Procedural Techniques for City Generation.*

Outline

- Context
  - Problem Statement
  - Initial Solution
  - Proposed Solution
- Types of Procedural Techniques
- How to Apply in City Generation?
- Wrap-up

Problem Statement

- Desire for more:
  - Detail
  - Realism
  - Scale

Initial Solution

- Hire more artists
- Problem:
  - Number of artists not proportional to content yield
  - Increased cost
    - Improve game play
    - Develop additional features

Proposed Solution

- Use Procedural techniques:
  - Used in computer graphics for over 20 years to:
    - Create 3D texture of natural materials
      - e.g. marble, wood
    - Visualize realistic natural features
      - e.g. terrain, lakes, trees, shrubs
    - Generate detailed cellular textures
      - e.g. skin, bark
  - Recently used to:
    - Simulate special effects
      - e.g. particle systems

Proposed Solution

- Key concept:
  - 1- Describe entity in terms of instructions
  - 2- Call instructions when needed
    - Provide parameters to create instances with varying characteristics.
- Benefit:
  - Can generate content quickly and efficiently

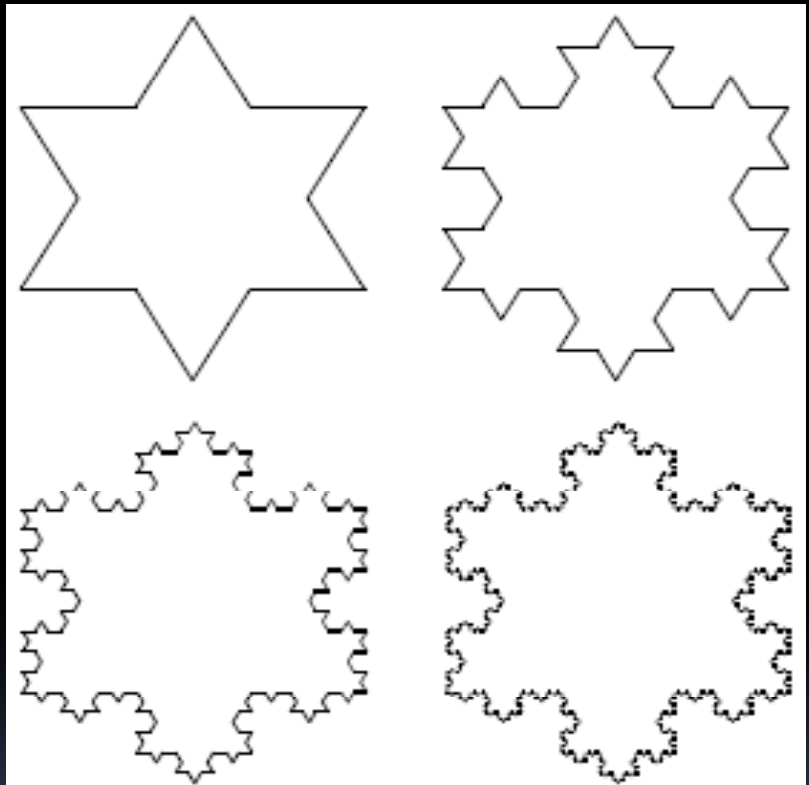
Types of Procedural Techniques

- Fractals
- L-Systems
- Perlin Noise
- Tiling
- Voronoi Texture Basis

Fractals

- Property of fractals:
  - Contain large degree of self similarity
- Generate complex models from the recursive application of simple models.
- Issue:
  - Limited to self-similar structures

Fractals Examples



The first four iterations of the Koch snowflake

IFS Fractal Ferns

L-Systems

- Lindenmayer System (L-System)
  - Originally: developed to study bacteria replication and growth patterns of simple organisms (e.g. algae)
  - Now: used in computer graphics to generate fractals and to model plants realistically
- Central concept: rewriting
- Benefit: more flexible than fractals

L-Systems Examples:
Thue-Morse System

Input parameters:

V = {a,b}

w = a

P1 : a ⟶ ab

P2 : b ⟶ ba

Results:

w: a

n = 1: ab

n = 2: abba

n = 3: abbabaab

n = 4: abbabaabbaababba

L-System Examples

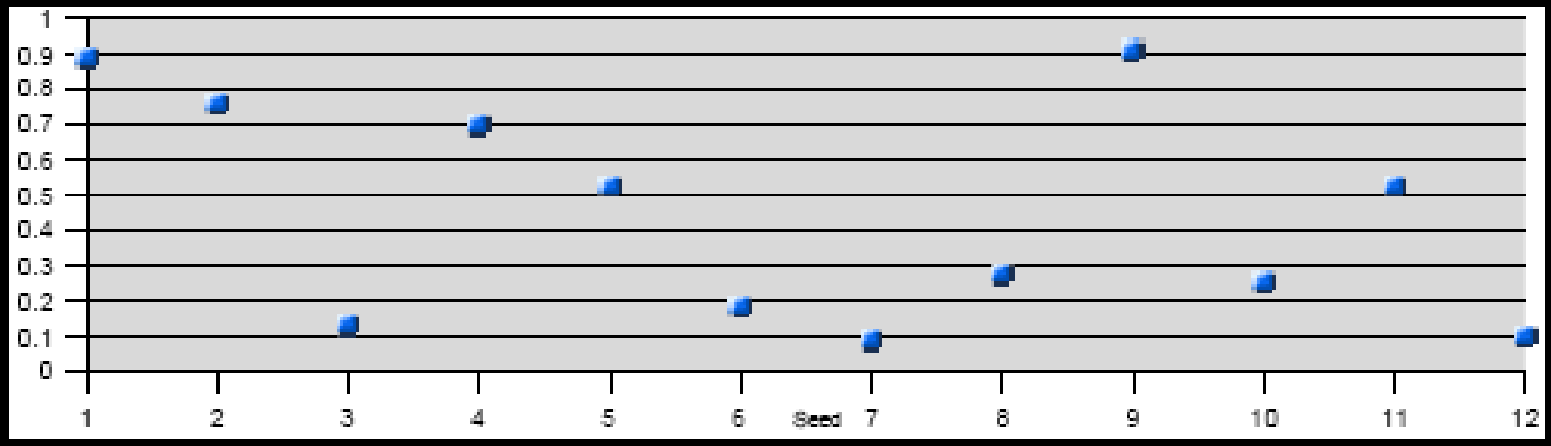
Perlin Noise

- Developed by Ken Perlin to create more "natural looking" textures
  - for use in the film Tron (1982)

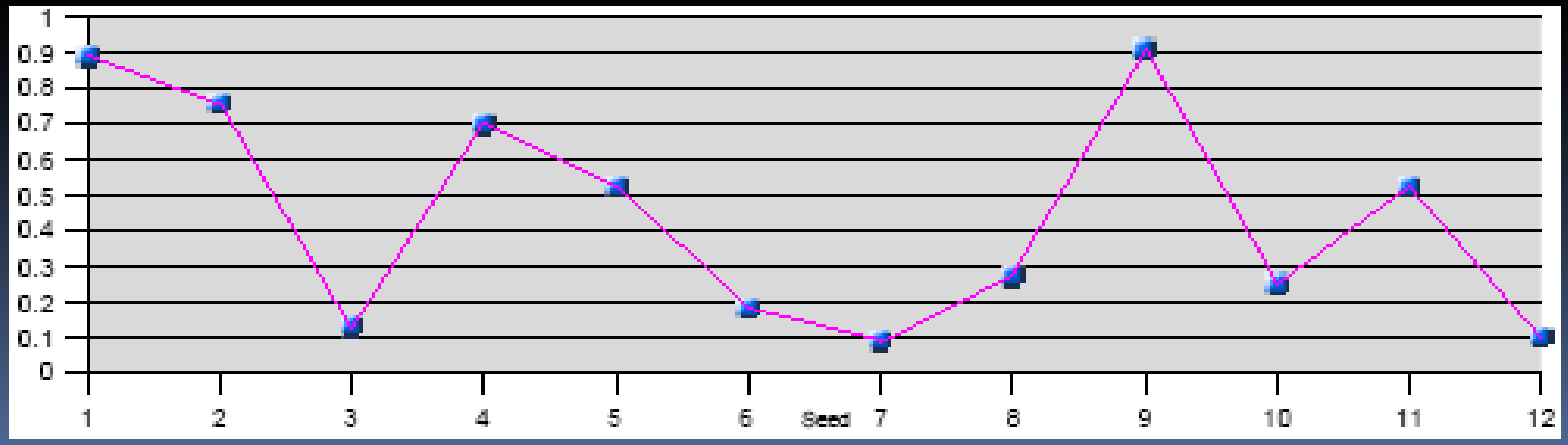
- 3 Steps:
  - 1 – Noise function
  - 2 – Interpolation function
  - 3 – Turbulence

Perlin Noise

Step 1: Noise Function

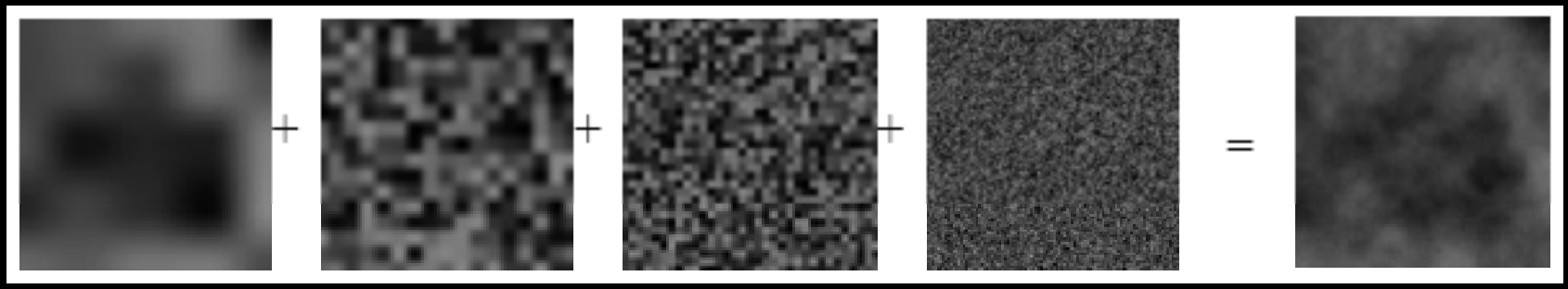


Step 2: Interpolation Function



Perlin Noise

Step 3: Turbulence



Perlin Noise Example

© 2003 M. GIULI Terragen Artist

Perlin Noise

- Benefits:
  - Parametric control
  - Minimal storage management
  - Tile-able output

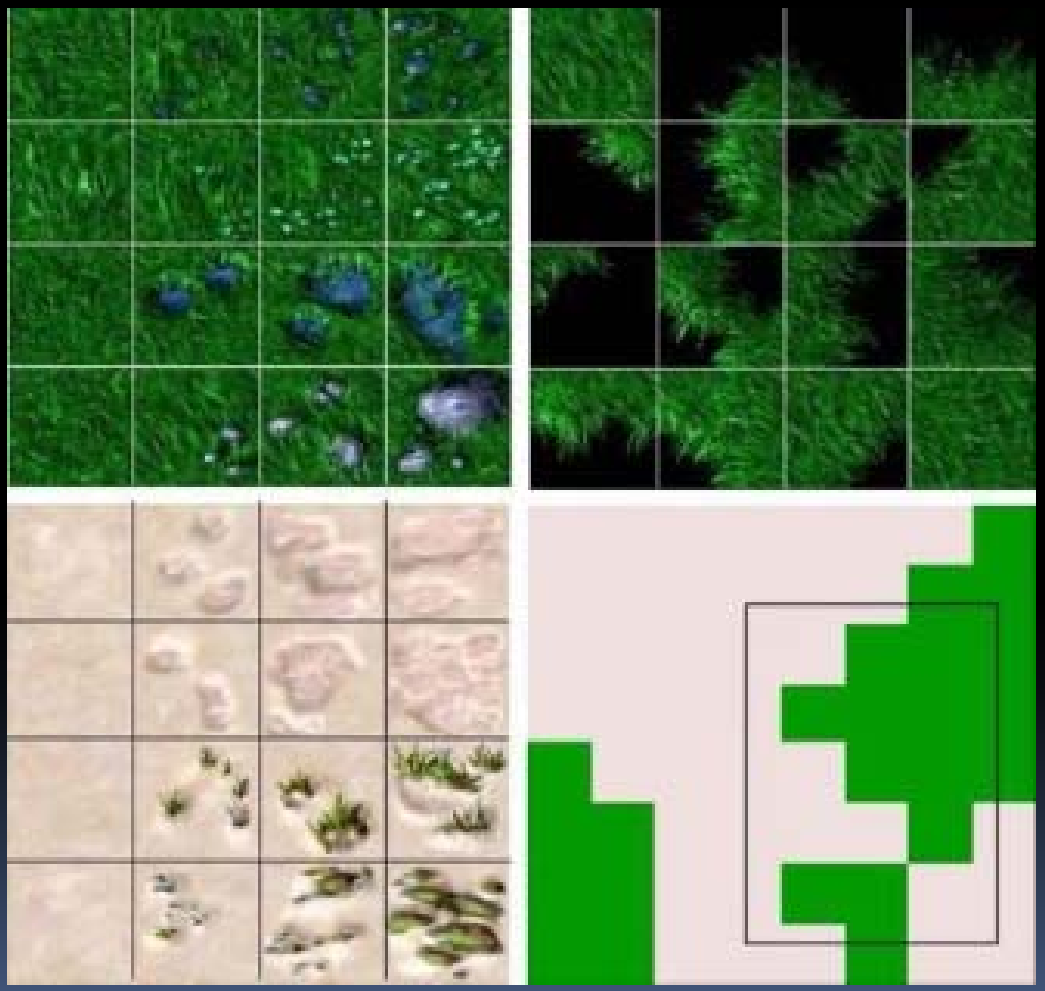
Tiling

- Most basic technique
  - used in many classic games like Sonic, Mario
- Now, used as multi-texturing to create highly detailed and varied textures from layers of base textures.
  - create terrain by applying several layers of detailed tile-able textures
    - textured layer examples: rock, grass, sand, snow

Tiling

Extended Algorithm:

- Use stochastic information
  - e.g. probability distribution map



Warcraft®
© 2002 Blizzard Entertainment

Tiling

Benefits:

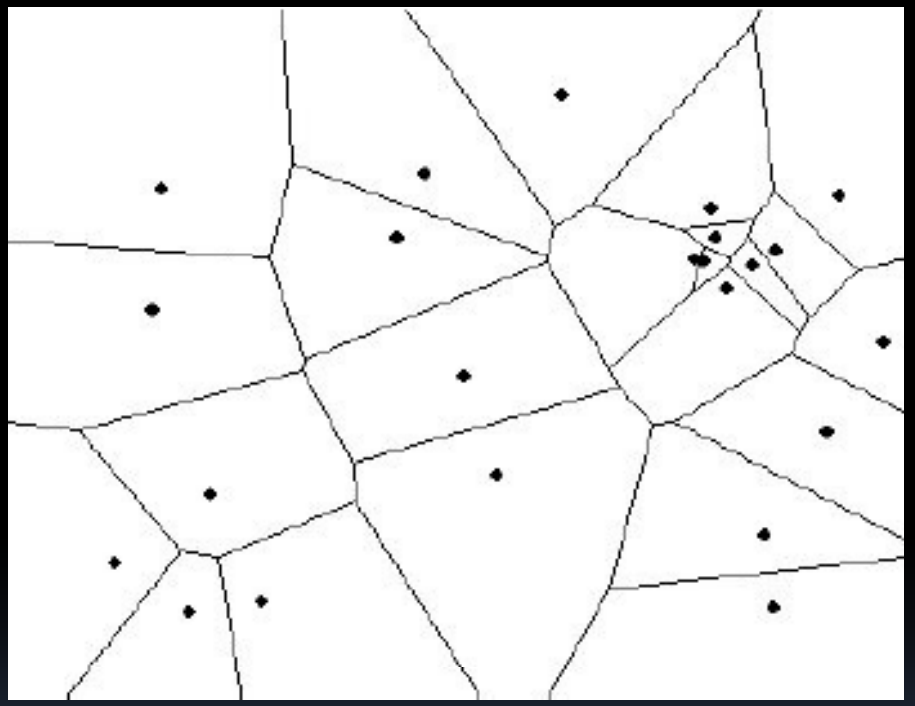
- Small input set
- Minimal storage and memory requirements

Voronoi Texture Basis

- **Worley Algorithm:** partition space into a random array of cells, creating cellular looking textures
- Traditionally, used in many scientific applications
  - e.g. spacial analysis, urban settlement analysis, geology, ecology and robotics
- Now, used to:
  - complement existing techniques
    - e.g. Perlin Noise
  - generate cellular surfaces
    - e.g. skin, bark

Voronoi Texture Basis

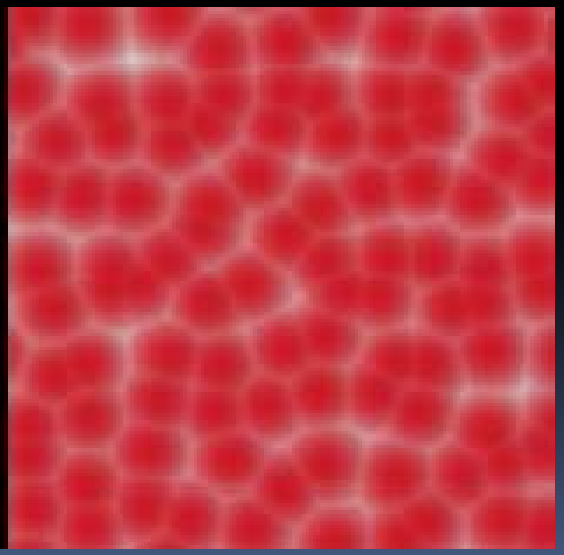
- Result of the position of the original points
- Create wide range of patterns by using different points configurations



Voronoi Texture Basis

- Benefits:
  - create a variety of richly detailed cellular surfaces
  - use a small set of input parameters



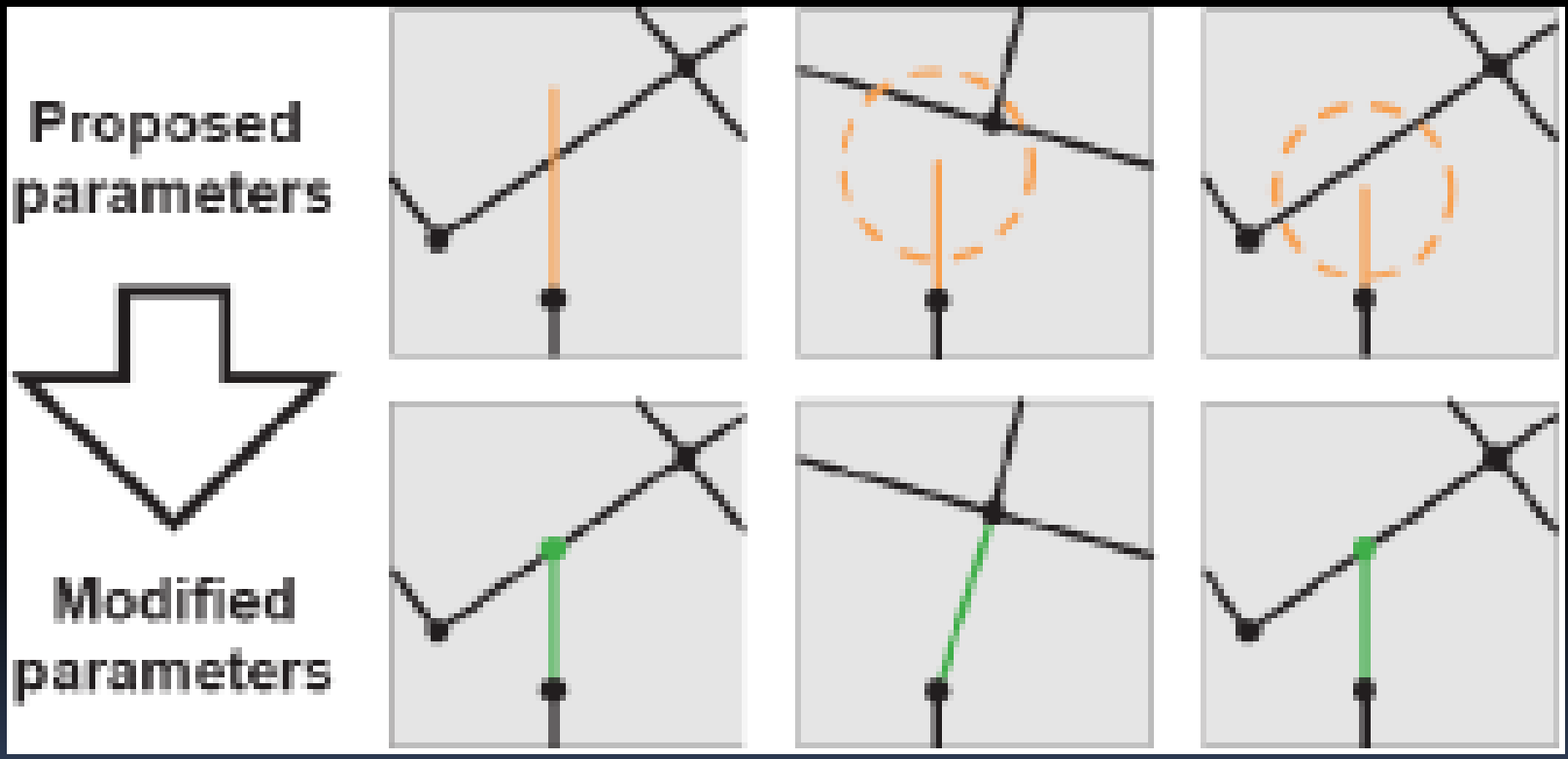


How to Apply in City Generation?

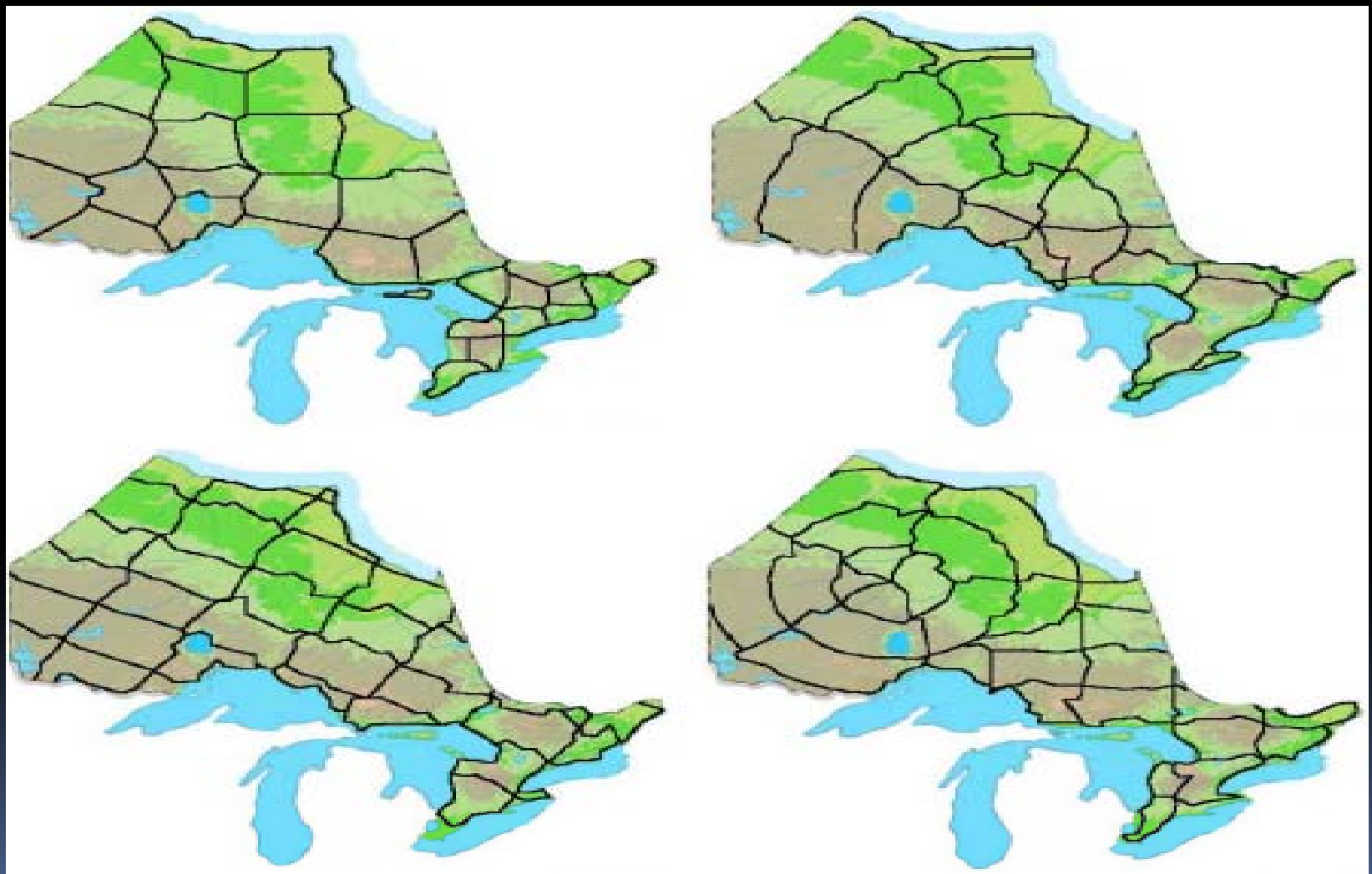
- Grid Layout: *Undiscovered City demo*
- L-Systems: *CityEngine*
- Template Based
- Split Grammar: *Instant Architecture*

Grid Layout: Undiscovered City Demo

L-Systems



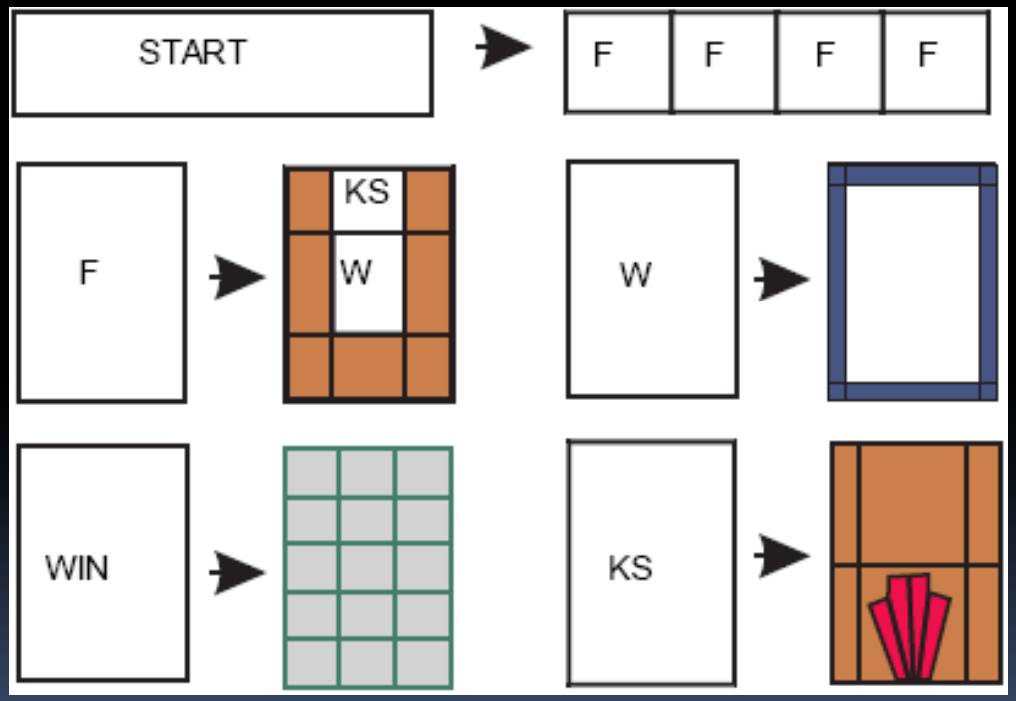
Template Based



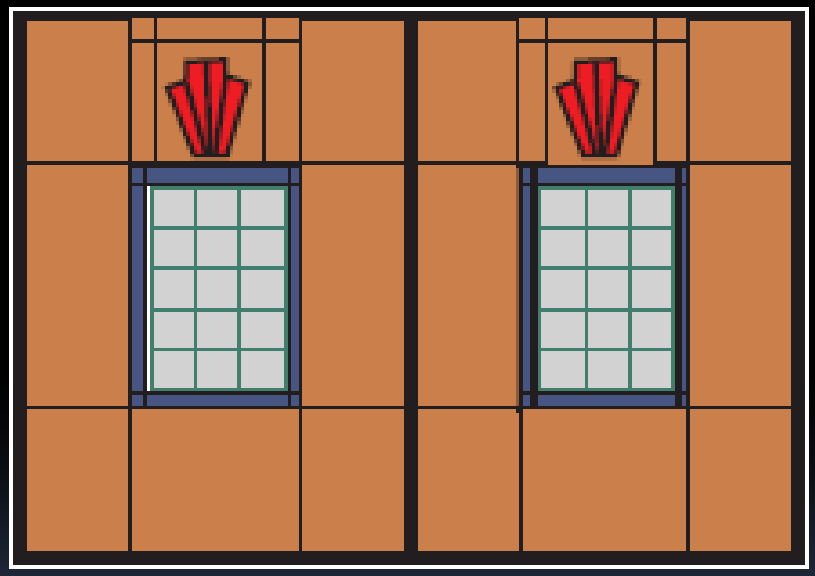
Population-Based Template, Radial Mode, Raster Mode and Mixed Mode.

Split Grammar

Rules



Results



Split Grammar: Instant Architecture

Wrap-up

- Benefit of procedural content generation:
  - Can create content rapidly and efficiently
- Project focus:
  - Influential factors when generating cityscapes:
    - Population, transport, environment, vegetation, elevation, geology, cultural influences
  - Automatically generate city maps
    - Focus on road networks

Questions?