Model Driven Engineering
Map Generation

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Design Space Exploration

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Design Space Exploration

- Find good / best instance
- Steps:
  1. Generate a candidate
  2. Check the candidate for feasibility
  3. Evaluate the candidate
  4. Repeat
- Several algorithms [1]:
  - Exhaustive
  - Random
  - Hill Climbing

[1] Denil, J., Han, G., Persson, M., Liu, X., Zeng, H., Vangheluwe, H., 2013. Model-driven engineering approaches to design space exploration. Tech. rep

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L-System: Introduction

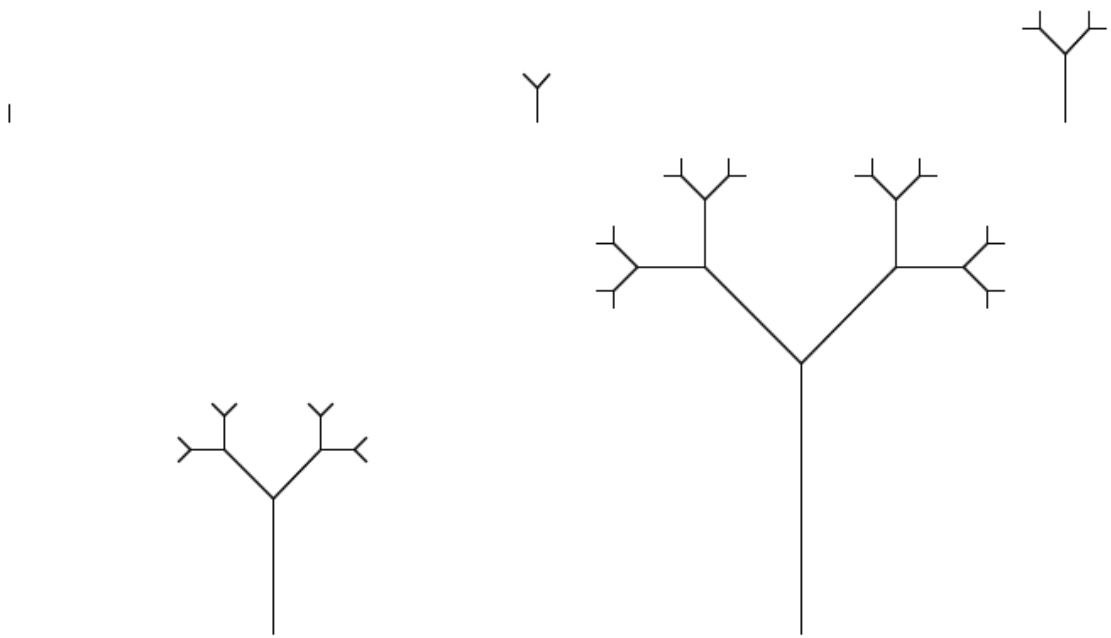
- Introduced to model plant growth
- G = (V, ω, P)
  - An alphabet V
  - An initial string ω
  - A set of rules P
- Many extensions

L-System: Example

$V = 0, 1, [,], +, -$

$\omega = 0$

$P = \{(1 \rightarrow 11), (0 \rightarrow 1[-0]+0)\}$



L-System: Use

$$V = \begin{cases} M: & \text{map growth entity} \\ I: & \text{intersection} \\ T: & \text{two-way road} \\ O: & \text{one-way road} \\ [: & \text{store state} \\ ]: & \text{restore state} \\ +: & \text{angle } + 90^\circ \\ -: & \text{angle - } 90^\circ \end{cases}$$

$$\omega = I\left[+M\left(n\right)\right]\left[-M\left(n\right)\right]\left[++M\left(n\right)\right]M\left(n\right)$$

$$P = \begin{cases} P_1: & M\left(n\right) & \rightarrow & T\left(x\right)I\left[+M\left(\frac{n-x}{3}\right)\right]\left[-M\left(\frac{n-x}{3}\right)\right]M\left(\frac{n-x}{3}\right) \\ P_2: & M(0) & \rightarrow & \epsilon \\ P_3: & T(x) & \rightarrow & O(x) \end{cases}$$

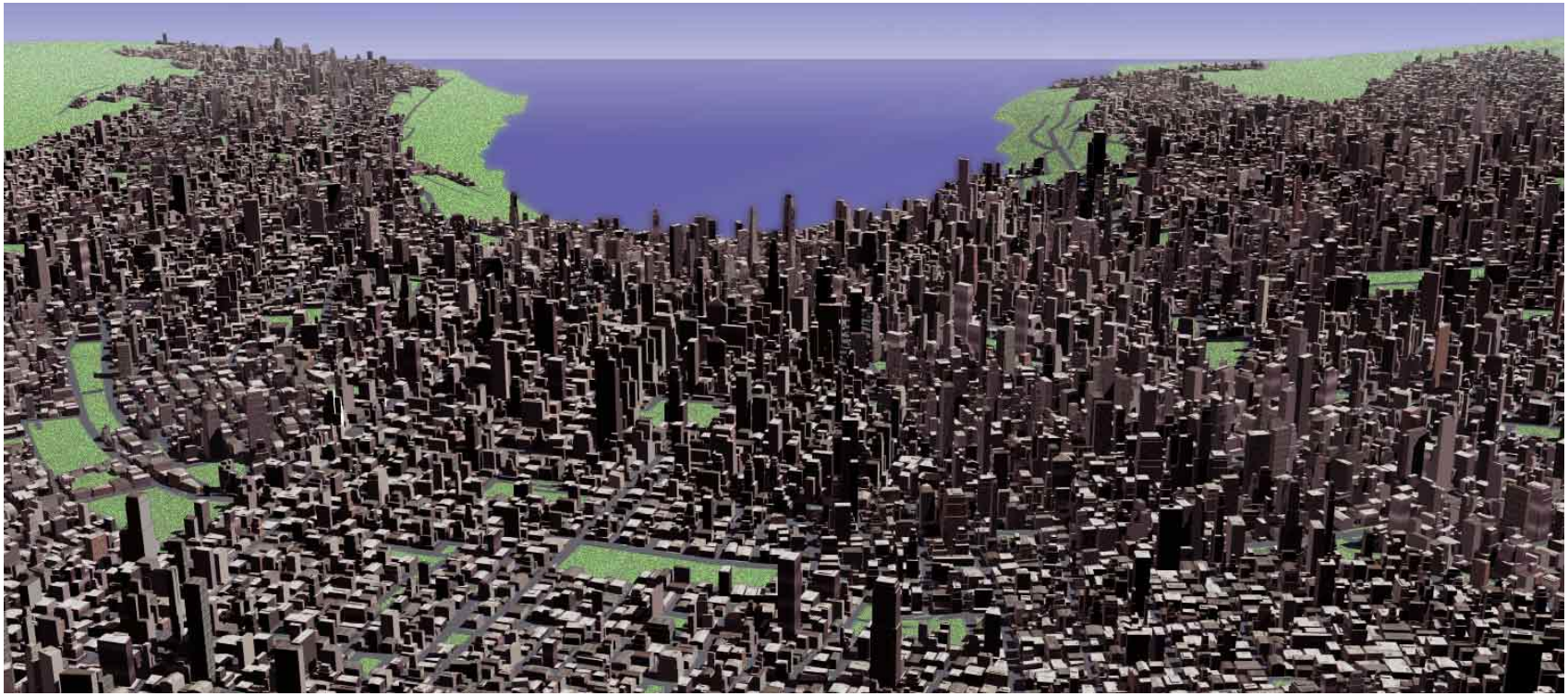
L-System: Use

Difficulties:

- Randomness $\rightarrow$ Stochastic L-Systems
- Analysis $\rightarrow$ Interpret string

L-System: Use

CityGen Engine [2]:



[2] Parish, Y. I. H., Müller, P., 2001. Procedural modeling of cities

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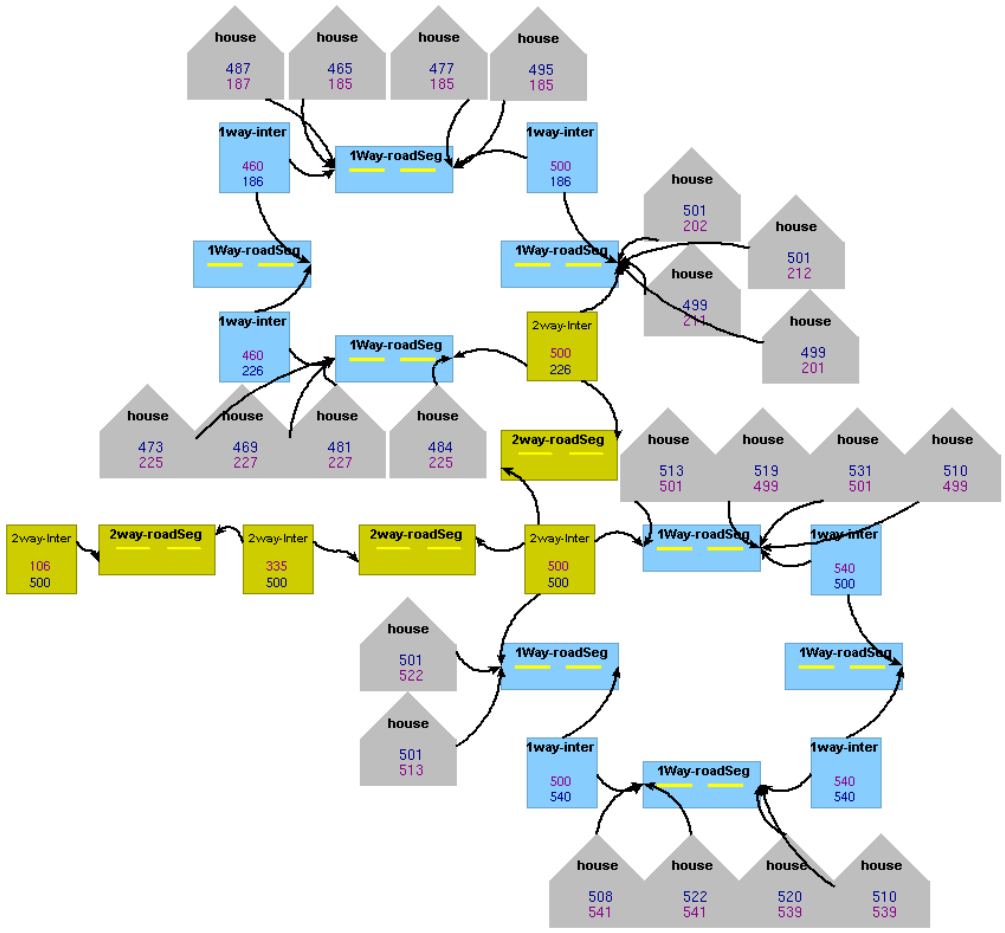
Graph Transformation: Related Work

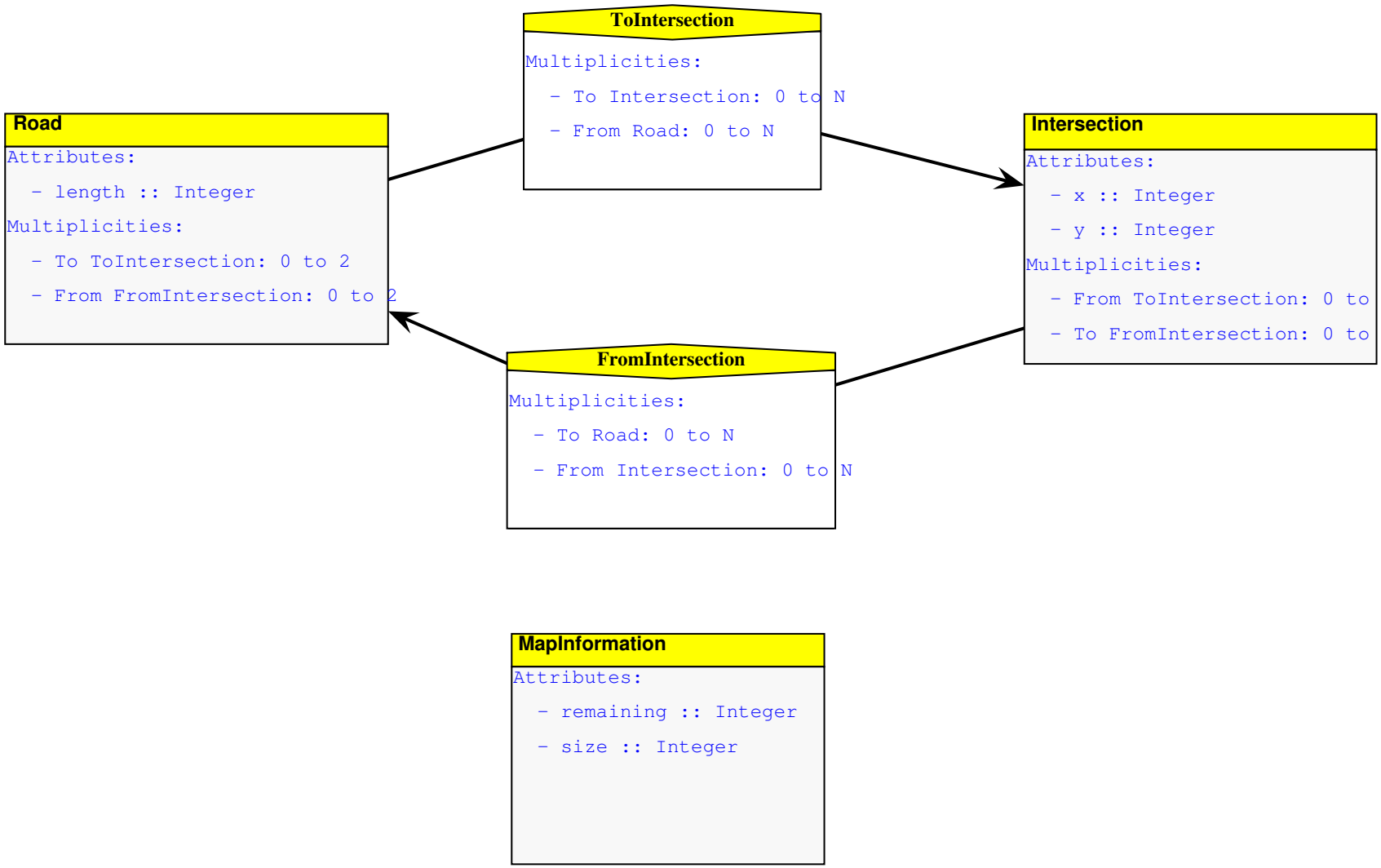
Riry Pheng [3]:



[3] Pheng, R., 2008. Procedural modeling for city map generation - final report

Graph Transformation: Project

Meta Model:



Graph Transformation: Project

Rules:

- Expand: North, East, South, West
- GrowRoad
- ConnectIntersections
- OneWay

Graph Transformation: Project

Feasibility:

- Strongly Connected Component

Desired Properties:

- Road distance close to Manhattan distance
- Minimize intersections on trajectory
- Cover as much as possible
- Roads are evenly distributed
- Multiple routes to an intersection

Metrics:

- Longest path
- Average minimal cut

Graph Transformation: Project

Space is huge $\Rightarrow$ algorithm should produce results fast.
Algorithm:

1. Select the candidate with the highest score
2. Generate all children
3. Check and evaluate each child
   - Not feasible or lower score: reject
   - Higher score: add as candidate
4. Repeat

Graph Transformation: Project

Figure: The initial map

Graph Transformation: Project

Figure: Iteration 1

Graph Transformation: Project

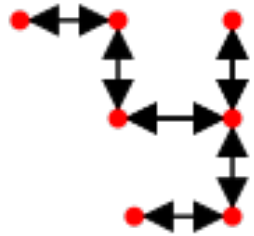


Figure: Iteration 10

Graph Transformation: Project

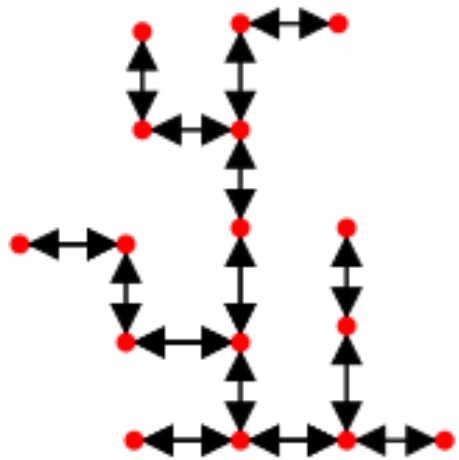


Figure: Iteration 50

Graph Transformation: Project

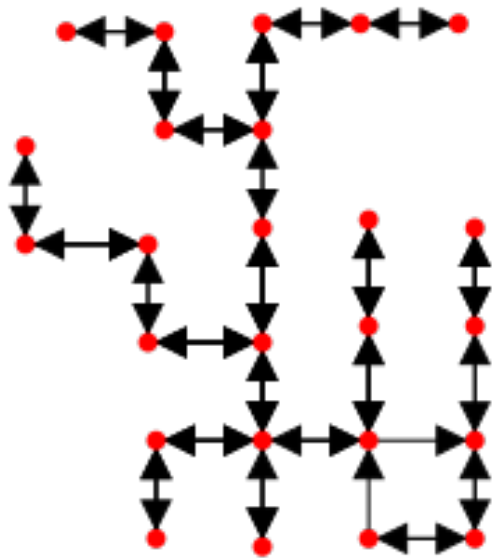


Figure: Iteration 100

Graph Transformation: Project

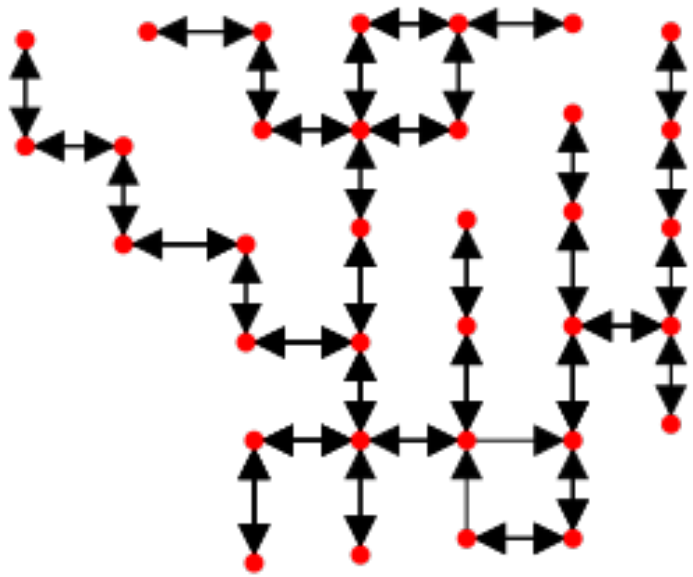


Figure: Iteration 150

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Simulation: PyDEVS [4] Model

- Cars move from intersection to intersection (trajectory)
- Only 1 car at an intersection
- Car changes speed when:
  - Entering a new road
  - Car before him changes its speed
  - Reaching end of the road

[4] Bolduc, J.-S., Vangheluwe, H., Van Tendeloo, Y., 2000 - 2013. URL `http://msdl.cs.mcgill.ca/projects/projects/DEVS/`

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Conclusion:

- Good metric is most important
- Time-expensive

Future Work:

- Houses, Stores, Offices, ... $\rightarrow$ Simulation
- Multiple lanes, traffic lights, maximum speed
- Initially start with Houses, etc and generate road network