Interactive Generation of Cities for Real-Time Applications

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Overview

We present a design for an interactive city generation system for use in real-time applications. Our method is to apply procedural techniques to allow the generation of a city and hence enable features such as dynamic gaming environments and on-line distribution. An interactive application is outlined to manage the generation process from primary road creation to building construction. The focus of the system is on creating realistic large scale road networks and building models suitable for real-time rendering.

The criteria used to evaluate a procedural solution are often the detail, complexity, heterogeneity and realism of the output. These indicators are crucial to the success of our system, but are not our only goals a number of additional goals require consideration.

- **Accessiblity** - Input data such as geographical maps or geo-statistical data should not be prerequisite to using the system.
- **Interactivity** - City generation can be fully autonomous but by allowing the option of user interaction the city can be tailored to specific requirements. The user can also control the patterns that the city is formed from on a local and global scale.
- **Real-Time** - Rendering considerations must be taken into account for real-time exploration of the city. A city model is a very large data set and techniques like selective culling, paging and level of detail should be implemented.

Our approach to achieving these goals is to design a system that is comprised of three major components: primary *road generation*, *secondary road generation* and *building generation*. The components will be integrated in a standalone application with all parameters and controls accessed through a visual interface providing an accessible workspace to perform city generation.

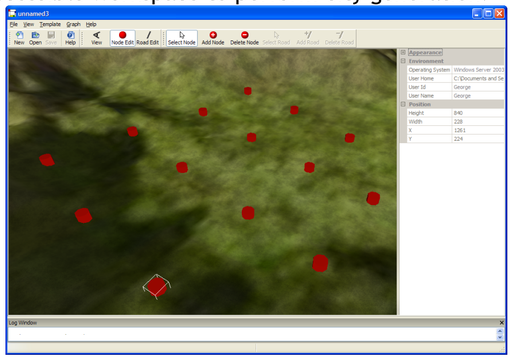


FIGURE 1: Interactive application serves as a one-stop-shop for city generation.

Primary-road templates

The primary road generation component utilises templates [Sun et al. 2002] that encapsulate common city road network patterns such as raster, radial, hierarchical and cellular. These templates are applied to a terrain in the form of an interconnected graph. The edges of the graph, the roads, can be automatically deformed by terrain characteristics such as steep gradients, water levels and other obstacles. The resultant road network graph is editable using an interactive 3D interface. Streets can be added, deleted and moved using junctions as control points for easy manipulation.

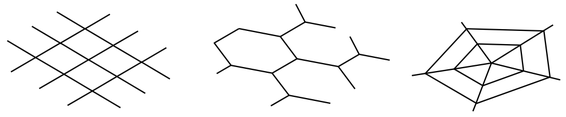


FIGURE 2: Primary road network templates

Secondary-road generation

From the primary road network graph closed loops create a series of enclosed cells. Each cell is self-contained and requires only the surrounding road loop and a small set of local and global parameters to execute road generation. A technique similar to that used in the CityEngine [Parish et al. 2001] based on L-systems can be applied within each cell generating roads that service the cell land area by providing access to and from the primary road network. Global and local parameters for each cell can be specified to control the operation of the secondary road generation. Our system aims to provide an environment in which these parameters are easily accessible and their effect can be viewed live.

Building construction

Buildings can be placed on the lots created from the secondary road generation. Building geometry will be constructed using L-systems taking several different building usage types into account including commercial, industrial, and residential with these usage types either stochastically assigned by the system or explicitly specified by the user via the interactive interface.

Real-time rendering

Real-Time rendering is possible in our design via the provision of a number of optimization features: *city cell paging*, *level of detail* and *real-time geometry generation*.

City cell paging

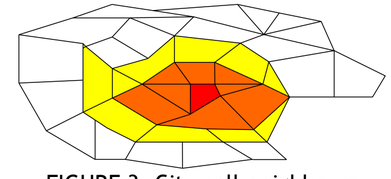


FIGURE 3: City cell neighbours

City cell paging is a concept similar to terrain paging systems, the primary road network forms a skeleton of the city containing the generation parameters for the entire city partitioned into cells. The road networks of each cell can be pre-emptively generated and loaded on demand.

Real-time geometry generation

The city dataset is minimized by storing only the primary road network and the generation parameters for each cell. Building structures and secondary roads can be stored in L-systems and generated at run time to create the required geometry. This provides a substantial reduction in memory usage by storing simple strings rather than complex geometry.

Level of detail (LOD)

As a result of geometry generation several variants of buildings can be constructed depending on the parameters used for instantiation.

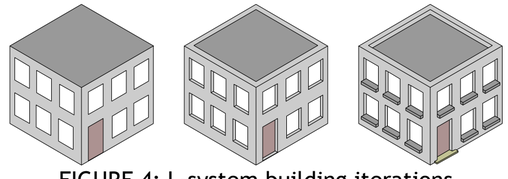
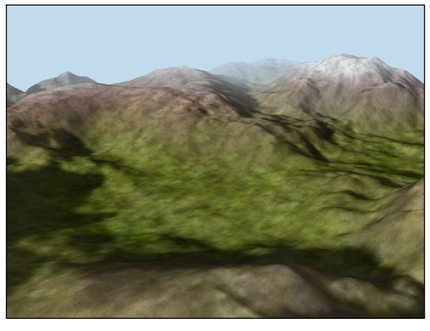
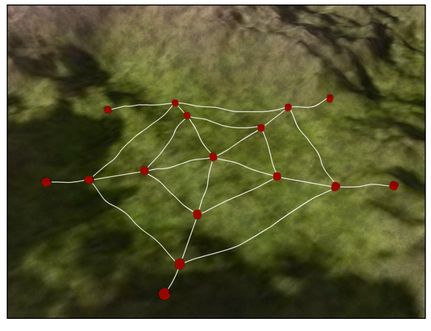


FIGURE 4: L-system building iterations

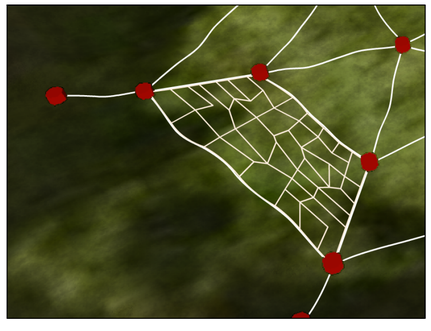
L-systems function using a string replacement technique that refines a basic model into a complex one over a series of iterations. A range dependant level of detail implementation can be provided by simply including a generation parameter that specifies the number of L-system iterations proportional to the distance between the camera and building.



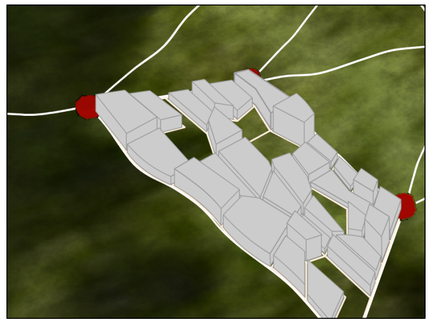
1 Terrain can be imported from a specialised tool or generated within the application itself.



2 Editable templates of common city patterns can be applied which adapt automatically to terrain and obstacles.



3 Closed loops from the primary road graph creates stand-alone cells that can generate a complete city section.



4 Building footprints can be created from the secondary network and can construct geometry using L-systems.

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