INTERACTIVE PROCEDURAL STREET MODELING

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Figure 1: This figure shows the three steps of our pipeline. The input water map is based on a stretch of the Benue River in Nigeria. Left: Starting from topographical water and park maps, the user designs a tensor field. Middle: The tensor field and further editing operations are used to generate a road network. Right: Three-dimensional geometry is created.

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Introduction

- Modeling 3D environments is time consuming
- Street networks is key
- Procedural techniques are efficient
- Grow like tree
- Lacks interactivity

- Produce alternative
- Add variety of user inputs
- Key is using tensor fields
Street Patterns

- Two dominant directions
- Tensor fields give two sets of hyperstreamlines
- Used to guide street network generation
- Users change tensor fields or street network graph
- Allows global and local operations and constraints
- Interactive editing
Pipeline

- Three stages
  - Tensor Field Generation
  - Street Graph Generation
  - 3D Geometry Generation

- Four maps as input
  - Water map
  - Park and Forest map
  - Height map
  - Population density map

- Manipulate tensor field
  - From boundaries
  - Brush stroke
  - Rotating with noise

- Major and Minor roads
  - Highways/residential
  - Stored as graph
  - Attributes stored at nodes and edges
Tensor Field Generation

- User constraints
- Topography
- N-S/E-W pattern
- Coastline
- Needs Flexibility
- Fields from each constraint generated and blended

- Edit fields
  - Regular and Radial Patterns
  - Brush Strokes
  - Topography
  - Rotation Fields
Figure 4: Left: A tensor field encoding a regular grid. Middle: The resulting street network. Right: A regular pattern found in Brooklyn, New York.

Figure 5: A procedurally generated radial pattern (middle) and its tensor representation (left). The map shown in the right is a radial pattern found in Scottsdale, Arizona.

Figure 6: Left: A map showing California Highway One. Right: A road network from a tensor field derived from the map boundary. Note a major road follows the coastline.
Figure 7: This figure shows the use of the brush stroke interface to orient streets.

Figure 8: This figure shows a regular major road grid (left) and a radial major road pattern (right) over slightly curved minor roads.

Figure 10: This figure shows a density map (left) (white represents high population density value while black indicates lower density) and a generated density transition on the right.
Street Graph Generation

- Alternate tracing major and minor hyperstreamlines
- Major street graph
  - Vertices: Intersections of major and minor hyperstreamlines
  - Edges: Segments between two vertices along a hyperstreamline

- Minor street graph
  - Regions of major graph
  - Can use separate tensor fields
  - Can be discontinuous across major roads

Figure 11: This figure shows a minor road network (right) generated based on the major road network (left)
Street Graph Editing

- Road Segment Manipulation
  - Create/Remove Segments
- Vertex Manipulation
  - Move Vertices
- Seed Point Creation
  - Insert New Streets
- Street Displacement
  - Move a Street
- Layered Editing
  - Draw random street on current street network
- Graph Noise
  - Add irregularities
- Local Sections Replaced
**Figure 12:** Left: This map shows an example from Chicago, where a single street is laying over an otherwise regular north-south grid pattern. Right: A similar pattern is created using our system.

**Figure 14:** This figure shows crack patterns in Missouri (left) and a procedurally generated patterns using our system (right).

**Figure 13:** This figure shows example maps from Manhattan, New York City. Left: Occasionally cells are merged together (1) or partially split by dead ends (2). Right: Slight irregularities can be seen in a regular grid (3).

**Figure 15:** This figure shows that a park can be inserted into an existing street network (left). Notice that the roads in the park region have a sparser density (right).
Initial Layout: 5 min
Fine Tuning & Experimentation: 30-60 min
Figure 18: A street graph for Manhattan, NY, USA generated using our tool.
**Strengths**
- Quick generation of initial layouts
- Flexibility
- Tensor fields modeling of street patterns

**Limitations**
- Single resolution
- Difficult to modify tensor field at significantly different scales

**Future Work**
- Multi-scaling editing
- Tensor fields to model cracks, fracture patterns, leaf venation patterns, bark, and ice crystals
- Image-based editing techniques

**Application**
- Content creation
- Games and movies