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From Stucco to Stairwells:  Inferring Attributes and Floorplans from Limited Geospecific Data

Revised title:  Same as original title

Presented in (input and Bold one): (WG 10, CG__, Special Session 2, Poster, Demo, or Tutorial):

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UNCLASSIFIED AND APPROVED FOR PUBLIC RELEASE
From Stucco to Stairwells: Inferring Attributes and Floorplans from Limited Geospecific Data

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Approved for public release, distribution unlimited

Outline

• Requirements
• Urban Terrain Zones (UTZ)
• Statistical Geotypical Building Attribution
• Geotypical Building Interior Configuration Layout
(Stucco and Stairwell) Inferencing Requirements

• Fully data driven
• Tunable to any geo-region
• All input geospecific attribution preserved
• Scaleable to real-world sized cities
• Must be executable as a fully automated process
• User must be able to override any aspect of the process
UTZs Defined

- A Classification system based on function and spacing[1].
- Areal Features which enclose buildings of similar size, spacing, and function.

<table>
<thead>
<tr>
<th>Function</th>
<th>Attached (A)</th>
<th>Discrete Clustered (Dc)</th>
<th>Discrete Open (Do)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Commercial core</td>
<td>A1</td>
<td>Dc1</td>
<td>Do1</td>
</tr>
<tr>
<td>2. Apartments</td>
<td>A2</td>
<td>Dc2</td>
<td>Do2</td>
</tr>
<tr>
<td>3. Single-family Homes</td>
<td>A3</td>
<td>Dc3</td>
<td>Do3</td>
</tr>
<tr>
<td>4. Industrial</td>
<td>A4</td>
<td>Dc4</td>
<td>Do4</td>
</tr>
<tr>
<td>5. Commercial Ribbons</td>
<td>A5</td>
<td>Dc5</td>
<td>Do5</td>
</tr>
<tr>
<td>6. Institutional</td>
<td>A6</td>
<td>Dc6</td>
<td>Do6</td>
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<td>7. Former Agricultural</td>
<td></td>
<td>Dc7</td>
<td></td>
</tr>
<tr>
<td>8. Shanty Towns</td>
<td></td>
<td>Dc8</td>
<td></td>
</tr>
</tbody>
</table>

UTZs, a Larger Example
Attribution Inferencing

- Given UTZ and building footprint area, generate attribution
  – Height, construction type, surface material composition, etc.
  with frequency distributions characteristic of a real city
- Appropriately deal with outliers
- Clustering algorithm classification method
  – Optimally clusters building areas within each UTZ
  – “K-means” – minimizes total within-cluster variance
  – Known as “Jenks’ Method” in geospatial community
Attribute Inferencing Algorithm

1. For the world (off-line)
   - Prepare table of “adjacent UTZs”

2. For the city being modeled (off-line)
   - Generate statistics over all UTZ polygons of (each) given type, producing
     - 5 Jenks’ classes clustering building footprint area
     - Recording min/max/mean/std deviation
     - Assignment of “core classes”
       - To deal with outliers
       - Optional user intervention
3. For each Building
   - From UTZ and area, lookup Jenks’ class
     - If class is “core”, use class statistics
     - If class not core, (temporarily) re-assign UTZ via best match among adjacent UTZs
       - Find UTZ with a core class of similar footprint area
       - New UTZ must be semantically adjacent to original
       - Use class statistics of temporary UTZ and class
Actual LIDAR Heights
Case 1: Fully Random

- “Flat Histogram”
- Min, Max, taken from original LIDAR heights
- Mean = Std. Dev. = $\frac{1}{2}(\text{Max} - \text{Min})$
- Looks like utter chaos
Case 1: Fully Random
The Real SLC
Case 2: One UTZ Polygon

- Min, Max, Mean AND Std. Dev taken from LIDAR heights.
- Low mean and std. dev for the entire dataset “flattens” all buildings.
Case 2: One UTZ Polygon
The Real SLC
Case 3: Multiple UTZs

- Min, Max, taken from LIDAR data, for each UTZ polygon
- Each UTZ has a “flat” distribution (Mean = STDEV = \( \frac{1}{2}(\text{Max} - \text{Min}) \))
- “Neighborhoods” of similar heights start to form, but the suburbs have some “towers” and there’s little differentiation between office hi-rise vs. warehouse
Case 3: Multiple UTZs
The Real SLC
Case 4: Accurate Mean, STDEV

- Min, Max, Mean, Stdev all computed from LIDAR data, on a per-UTZ basis.
- All Jenks classes accepted as core, all building remain in their UTZs.
- Looking more city-like
Case 4: Accurate Mean, STDEV
The Real SLC
Case 5: Analyst Assignment of Jenks’ Core Classes

- Jenks’ classes 3-5 core
- More of the down-town buildings are tall.
Case 5: Analyst Assignment of Jenks’ Core Classes
The Real SLC
Case 5: Analyst Assignment of Jenks’ Core Classes
The Real SLC
Interior Configuration

• Literature replete with automated layout software
  – Non-linear optimization, not scalable
• Ad hoc process
  – Door near road
  – Linear or circular hallway depending on footprint size and aspect ratio
  – Shaft off hallway
  – Room filling
Geospecificity

Geotypical Only

Urban area populated with buildings using modeler’s "artistic license"
Buildings may be aligned to geospecific roads
Building façade textures judged "reasonable" for particular urban region
Either no interiors or arbitrary interiors
Arbitrary but reasonable attribution

Full Geospecific

Geospecific building footprints
Actual building heights
Imagery-derived building facade textures
Interior layout from CAD drawings (including shafts, ducts, sewer, subterranean spaces)
Actual building name, BFC, other geospecific attribution

Geospecific building footprints
Actual building heights
Reasonable textures for UTZ type
Reasonable interiors for UTZ and BFC
Reasonable attribution for UTZ and BFC