City Model Generalization Quality Assessment using Nested Structure of Earth Mover’s Distance

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Outline

- Introduction
- Attribute Related Graph (ARG) generation
- ARG comparison with NEMD
- Case study
- Conclusions
Introduction

- Automatic generalization requires quality assessment
- Visual similarity is important
- Pattern recognition methods
- ARG+NEMD
ARG

- Represent the features of the models
ARG of City Model

- **Nodes**
  - Each building is a node
- **Relationships between nodes**
  - Spatial relationship between nodes
- **Example**

\[
v_1 = \{\text{ground plan } v_1\}
\]
\[
v_2 = \{\text{ground plan } v_2\}
\]
\[
r_{12} = (-5*(1/7), -5*(1/7))
\]
\[
r_{21} = (0.707, 0.707)
\]
ARG comparison  
- Distance between nodes

\[ d_{node}(v_1, v_2) = 0.5*D_{abs}(P_1, P_2) + 0.5*D_{rel}(P_1, P_2) \]

\[ D_{abs}(P_1, P_2) = 1 - \frac{\text{Area}(P_1 \cap P_2)}{\text{Max}(\text{Area}(P_1), \text{Area}(P_2))} \]

\[
\begin{array}{c}
P_1 \\
1 \\
2 \\
P_2
\end{array}, \quad
\begin{array}{c}
P_2 \\
1 \\
2 \\
P_1 \cap P_2
\end{array}, \quad
\begin{array}{c}
P_2 \\
P_1 \cap P_2
\end{array}
\]

\[ D_{abs} = 1 \ast 1/2 \quad D_{rel} = 1 \ast 0.25/2 \]
ARG comparison
- Distance between relationships

\[
r_1 = r(v_2, v_1) = (0.707, 0.707)
\]

\[
r_2 = r(v_3, v_4) = (1 \times 4/5, 1 \times 3/5) = (0.8, 0.6)
\]

\[
d_{\text{relation}}(r_1, r_2) = \frac{(0.707-0.8)^2 + (0.707-0.6)^2}{1+1} = 0.01
\]
ARG comparison
- NEMD calculation example

(a) Original building group

(b) Generalized building group
ARG comparison
- NEMD calculation example

\[ d_{\text{inner}}(v_i, v'_i, v_j, v'_j) = (1 - p) \times d_{\text{node}}(v_j, v'_j) + p \times d_{\text{relation}}(r_{ij}, r'_{ij}) \]

\[ d_{\text{note}}(v_0, v'_0) = 0.5 \times D_{\text{abs}}(P_0, P'_0) + 0.5 \times D_{\text{rel}}(P_0, P'_0) = 0.5 \times (1 - 1/3) + 0.5 \times (1 - 1/3) = 0.667 \]

\[ d_{\text{relation}}(r_{00}, r'_{00}) = 0 \text{ since } r_{00} = r'_{00} = (0, 0) \]

\[ d_{\text{inner}}(v_0, v'_0, v_0, v'_0) = (1 - p) \times d_{\text{note}}(v_0, v'_0) + p \times d_{\text{relation}}(r_{00}, r'_{00}) = 0.5 \times 0.667 + 0.5 \times 0 = 0.333 \]
ARG comparison
- NEMD calculation example

\[
D_{inner}(v_0, v'_0) = \begin{bmatrix}
    d_{inner}(v_0, v'_0, v_0, v'_0) & d_{inner}(v_0, v'_0, v_0, v'_1) \\
    d_{inner}(v_0, v'_0, v_1, v'_0) & d_{inner}(v_0, v'_0, v_1, v'_1) \\
    d_{inner}(v_0, v'_0, v_2, v'_0) & d_{inner}(v_0, v'_0, v_2, v'_1)
\end{bmatrix}
= \begin{bmatrix}
    0.333 & 0.875 \\
    0.667 & 0.910 \\
    1.056 & 0.323
\end{bmatrix}
\]

\[
d_{outer}(v_i, v'_{i'}) = \begin{cases}
    \frac{\sum_{n=1}^{Nc} \min(\text{Row}(D_{inner}(v_i, v'_{i'}), n))}{Nc} & \text{if } Nc < Nr \\
    \frac{\sum_{m=1}^{Nr} \min(\text{Col}(D_{inner}(v_i, v'_{i'}), m))}{Nr} & \text{if } Nc \geq Nr
\end{cases}
\]

\[
d_{outer}(v_0, v'_0) = (0.333 + 0.323)/3 = 0.219
\]
ARG comparison
- NEMD calculation example

\[
D_{\text{outer}} = \begin{bmatrix}
  d_{\text{outer}}(v_0, v'_0) & d_{\text{outer}}(v_0, v'_1) \\
  d_{\text{outer}}(v_1, v'_0) & d_{\text{outer}}(v_1, v'_1) \\
  d_{\text{outer}}(v_2, v'_0) & d_{\text{outer}}(v_2, v'_1)
\end{bmatrix}
= \begin{bmatrix}
  0.219 & 0.260 \\
  0.153 & 0.414 \\
  0.431 & 0.153
\end{bmatrix}
\]

\[
NEMD = \begin{cases}
\sum_{i=1}^{Nc} \min(\text{Row}(D_{\text{outer}},i)) & \text{if } Nc > Nr \\
\sum_{i=1}^{Nr} \min(\text{Col}(D_{\text{outer}},i)) & \text{if } Nc \leq Nr
\end{cases}
\]

NEMD of $G$ and $G'$: $0.219 + 0.153 + 0.153 = 0.525$
Case study

- City models are generalized by hand
- 10 Ph.D students from KTH are tested
- Select the better one they think from 2 results
Case study

(a) 5 buildings removed
NEMD: 12.86
10 votes

(b) Original Models

(c) 5 buildings removed
NEMD: 101.6
0 vote
Case study

(d) 5 buildings removed
   NEMD: 101.6
   0 vote

(e) Original Models

(f) 14 buildings removed
   NEMD: 50.0
   10 votes
Case study

(g) 25 buildings removed
NEMD: 164.5
1 vote

(h) Original Models

(i) 25 buildings removed
NEMD: 151.9
9 votes
Case study

(j) 14 buildings removed
NEMD: 50.0
7 votes

(k) Original Models

(l) 14 buildings removed
NEMD: 56.7
3 votes
# User survey results

<table>
<thead>
<tr>
<th></th>
<th>(a) : (c)</th>
<th>(d) : (f)</th>
<th>(g) : (i)</th>
<th>(j) : (l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>User survey</td>
<td>10:0</td>
<td>0:10</td>
<td>1:9</td>
<td>7:3</td>
</tr>
<tr>
<td>NEMD</td>
<td>12.9:101.6</td>
<td>101.6:50.0</td>
<td>164.5:151.9</td>
<td>50.0:56.7</td>
</tr>
<tr>
<td>NEMD difference</td>
<td>89.3</td>
<td>51.6</td>
<td>12.6</td>
<td>6.7</td>
</tr>
</tbody>
</table>
Conclusion

• ARG and NEMD for similarity evaluation
• The user survey shows the relationship between the proposed algorithm and the human visual perception
• Future improvement
  - Feature and relationship definition
  - Distance between nodes
  - Distance between relationships
  - Weights
Thanks for your attention!

Any Questions Please