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

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Outline

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

Introduction

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

ARG

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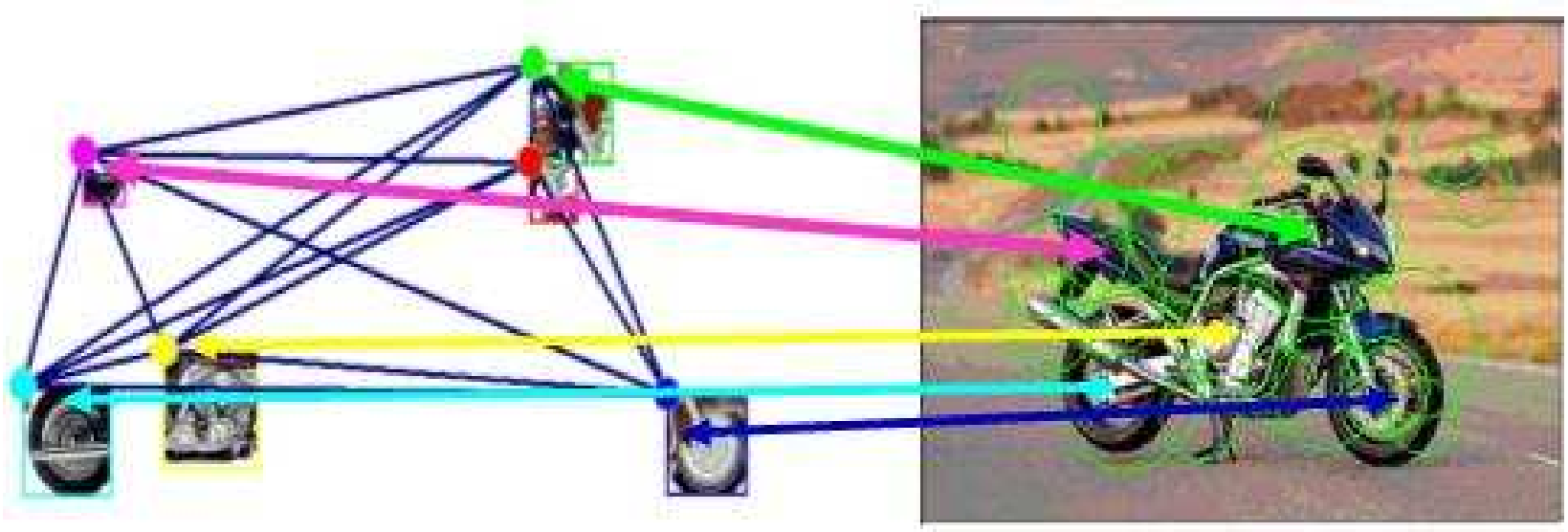
- Represent the features of the models



ARG of City Model

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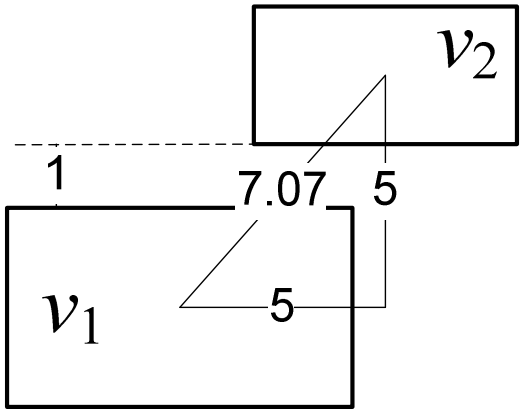
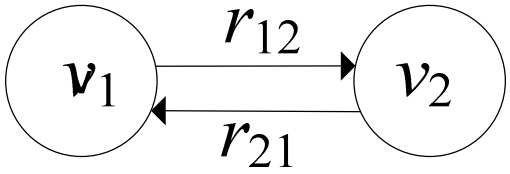
- Nodes
  - Each building is a node
- Relationships between nodes
  - Spatial relationship between nodes
- Example





v_1={ground plan v_1}
v_2={ground plan v_2}
r_{12}=(-5*(1/7),-5*(1/7))
r_{21}=(0.707,0.707)

ARG comparison
- Distance between nodes

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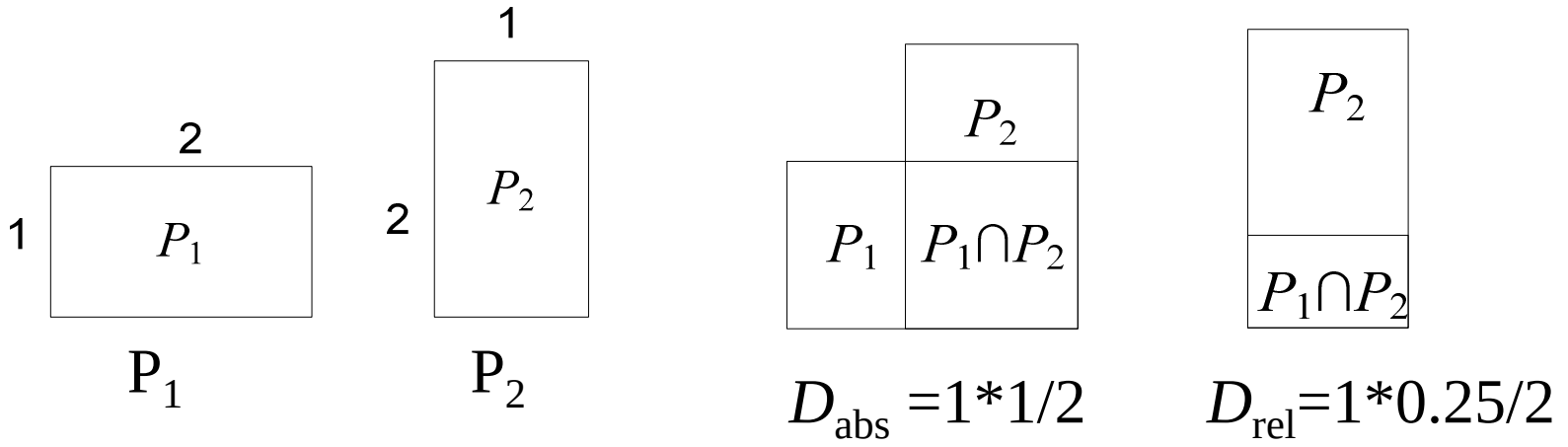
$$d_{node}(v_1, v_2) = 0.5*D_{abs}(P_1, P_2)+0.5*D_{rel}(P_1, P_2)$$

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



D_{abs} =1*1/2

D_{rel}=1*0.25/2

ARG comparison
- Distance between relationships

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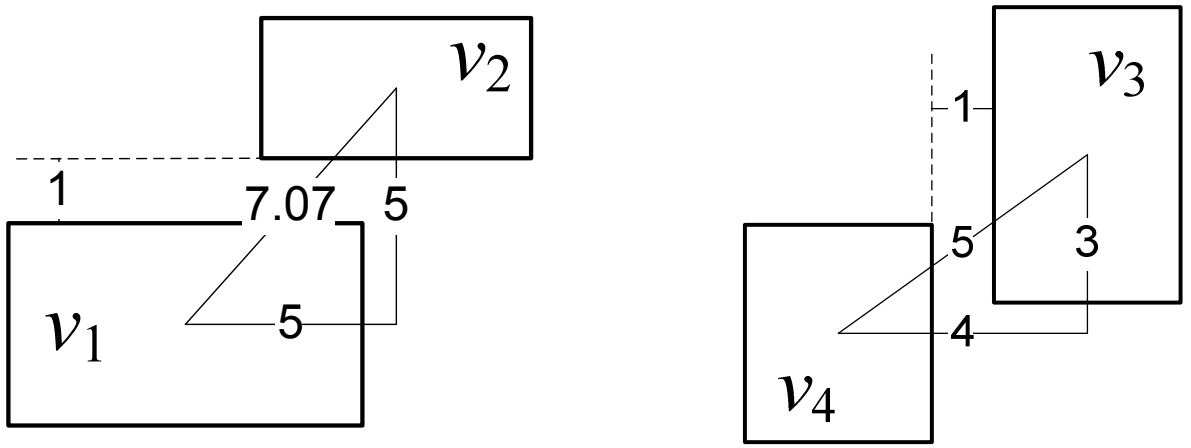

$r_1 = r(v_2, v_1) = (0.707, 0.707)$

$r_2 = r(v_3, v_4) = (1*4/5, 1*3/5) = (0.8, 0.6)$

$d_{\text{relation}}(r_1, r_2) = ((0.707-0.8)^2+(0.707-0.6)^2)/(1+1) = 0.01$

ARG comparison
- NEMD calculation example

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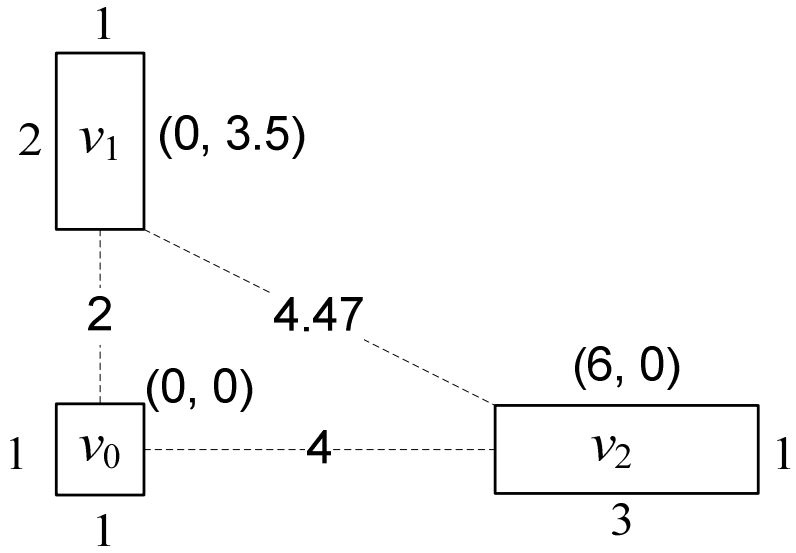
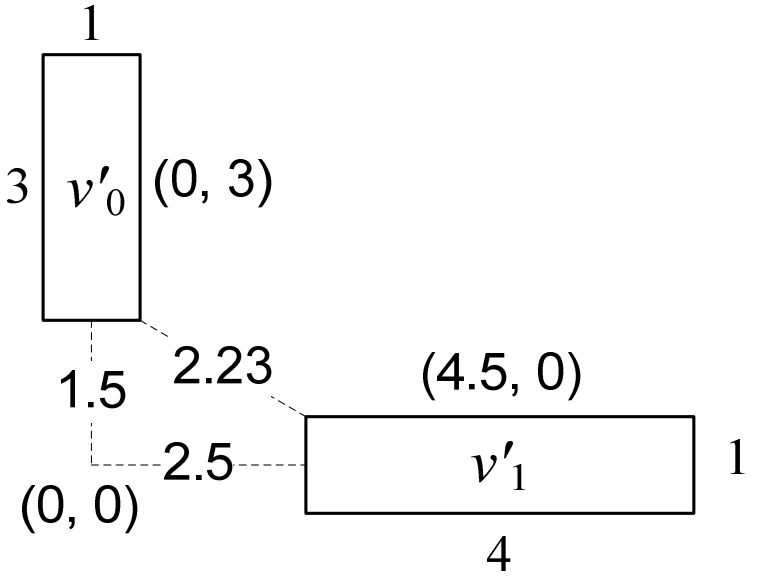
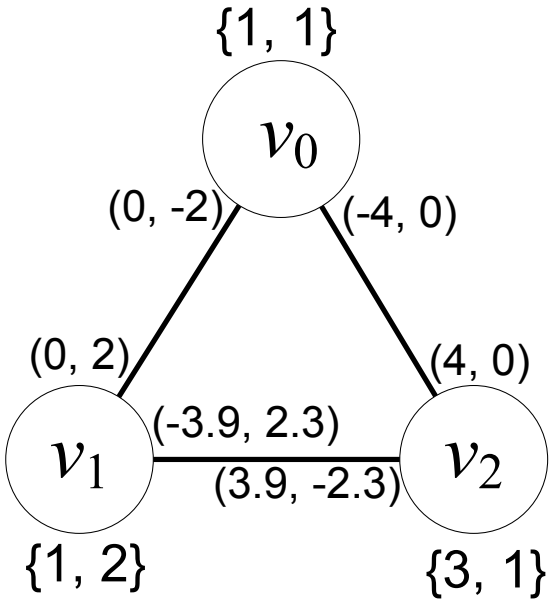


(a) Original building group

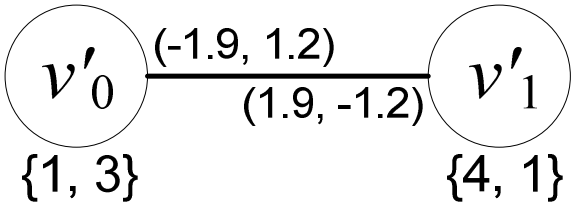


(b) Generalized building group

ARG comparison
- NEMD calculation example



(c) *G*: Original ARG



(d) G': Generalized ARG

$$d_{inner}(v_i, v'_{i'}, v_j, v'_{j'}) = (1-p)\times d_{\text{node}}(v_j, v'_{j'}) + p\times d_{\text{relation}}(r_{ij}, r'_{i'j'})$$

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

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

$d_{\text{inner}}(v_0, v'_0, v_0, v'_0)$ =(1-*p*)*$d_{\text{note}}(v_0,v'_0)$+*p**$d_{\text{relation}}(r_{00}, r'_{00})$=0.5*0.667+0.5*0=0.333

ARG comparison
- NEMD calculation example

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

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

$d_{\text{outer}}(v_0, v'_0) = (0.333+0.323)/3 = 0.219$

ARG comparison
- NEMD calculation example

$$D_{outer} = \begin{bmatrix} d_{outer}(v_0, v_0') & d_{outer}(v_0, v_1') \\ d_{outer}(v_1, v_0') & d_{outer}(v_1, v_1') \\ d_{outer}(v_2, v_0') & d_{outer}(v_2, v_1') \end{bmatrix} = \begin{bmatrix} 0.219 & 0.260 \\ 0.153 & 0.414 \\ 0.431 & 0.153 \end{bmatrix}$$

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

NEMD of G and G': 0.219+0.153+0.153=0.525

Case study

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- 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

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(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

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(g) 25 buildings removed
NEMD:164.5
1 vote

(h) Original Models

(i) 25 buildings removed
NEMD: 151.9
9 votes

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(j) 14 buildings removed
NEMD:50.0
7 votes

(k) Original Models

(l) 14 buildings removed
NEMD: 56.7
3 votes

User survey results

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	(a) : (c)	(d) : (f)	(g) : (i)	(j) : (l)
User survey	10:0	0:10	1:9	7:3
NEMD	12.9:101.6	101.6:50.0	164.5:151.9	50.0:56.7
NEMD difference	89.3	51.6	12.6	6.7

Conclusion

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- 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

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Thanks for your attention!

Any Questions Please