Comparison of Hierarchical Network Design Shape Grammars for Roads and Intersections

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Motivation
- Growing urbanization
- Different standards for network design between countries
- Missing evidence for standards in network design
- Growing number of software solutions for urban simulation and shape grammars, within urban design.

Initial settings

| Network element | Links [No. | Lane km] | Intersections [No. | Area | |
|-----------------|-----------|-----------|-------------------|------|
| Collector street | 0.8 | 0.6 | - | - |
| Major arterial | 1.3 | 1.1 | 0.3 | 0.1 |
| Highway | 1.4 | 1.2 | 1.2 | 2.5 |
| Freeway | 1.6 | 1.3 | 9.3 | 6.2 |

Search space

Objective function

\[ f = \sum \sum demand_{ij} \cdot travel_{ij} \]

Initial population definition containing random individuals.

Pseudo code

```
repeat
(1) Initial population definition containing random individuals.
for each pair do
(2) Recombination for new network individual
Choose 4 pairs of individuals randomly.
endfor
(3) Implementation of the hierarchical shape grammars.
(4) The generated individual with highest score is selected
for each individual return to the parent population.
end
```

Pheromone densities (left) and best intermediate networks (right).

Results

Shape grammars considered

<table>
<thead>
<tr>
<th>Shape grammar</th>
<th>Average score</th>
<th>Relative difference</th>
<th>Wilcoxon rank-sum</th>
<th>Average score</th>
<th>Relative difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>143'200</td>
<td>-</td>
<td>-</td>
<td>300'192</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>147'132</td>
<td>2.75%</td>
<td>0.0087%</td>
<td>-137'145</td>
<td>5.65%</td>
</tr>
<tr>
<td>C</td>
<td>147'798</td>
<td>-</td>
<td>-</td>
<td>297'301</td>
<td>-</td>
</tr>
<tr>
<td>D</td>
<td>157'690</td>
<td>8.90%</td>
<td>0.048%</td>
<td>-466'909</td>
<td>57.05%</td>
</tr>
</tbody>
</table>

Advantages
- Application in planning processes.
- Robust and reliable implementation.
- Easy implementation, adapted to state-of-the-art transport network optimization.
- Low computational requirements without a costly bi-level network optimization approach.
- Inclusion of spatial planning and architecture shape grammars.

Disadvantages
- Unknown impact of shape grammars in urban systems.
- Lack of a fundamental evidence base for shape grammars.

Applications
- Transport, land use and urban planning (3, 4, 5).

Network Design Shape Grammars

Definition
Shape Grammars describe in the form of rules how network elements of different types may be added to each other e.g. if a four lane road can be crossed by an access road. The rules depict how an existing planning state and geometry are extended to a more desirable state.

Example set of shape grammars for joining network elements of different hierarchical levels:

D -157’690 8.90% 0.048% -466’909 57.05%
C -144’798 - -297’301 -
B -147’132 2.75% 0.0087% -317’145 5.65%
A -143’200 - -300’192 -

In each state, a share of the density evaporates, as a learning strategy (like in ACO).

End

Visualizations

References