The influence of the visible views of the urban environment on cyclists’ route choices

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Introduction

• Urbanization; Cities continue to grow > Need for sustainable mobility

• Cycling as an active mode:
  • Healthy, sustainable, efficient
  • Preferred mode for daily activities
  • Increasing popularity > in Amsterdam has increased by 43% in the past 25 years

Better insight of mobility patterns and route choices of cyclists >
Understanding of measurable & perceived attributes

**Hypothesis:** Urban environment affects where cyclists travel
Research Question

To what extent do the directly visible views of the urban environment influence the route choices of the cyclists and how these different views can be measured?
**Q1.** Which determinants of the urban environment that have been identified in prior studies can be implemented in the current research?

**Q2.** How the cyclist’s route choices will be examined?

**Q3.** What is the added value of the point cloud, compared to the use of 2D data, as a method for investigating the visibility of cyclists in outdoor environment?

**Q4.** What is the role of space syntax in the current research?

**Q5.** Which cyclists’ routes should be used for the current research and how they can be filtered?

**Q6.** What is the proper number of observer points to be create for the visibility analysis?

**Q7.** What are the differences between the routes of the cyclists and the alternatives?
Literature research
What to measure?

Spatial Openness

“The amount of space perceivable to the viewer.”
(Kaplan et al., 1989)
How to measure?

3D Isovist

“The set of all points visible from a specific vantage point in space and with respect to the urban environment”
Case study: Amsterdam, NL
Datasets & Tools

Datasets
- Fietstelweek 2015 - GPS actual routes
- OSM alternatives - Openrouteservice
- 2D data - BGT and BAG
- AHN3 Point Cloud
- OSM street Network
- Urban Atlas – Copernicus 2012

Tools
- ArcGIS
- Python
- PostgreSQL
- Rhino 6
- QGIS
Almost 10,500 routes in the city of Amsterdam
Cyclists' movements

Top 3 Origins
- Centrum West
- Centrum Oost
- Indische Buurt

Top 3 Destinations
- Centrum Oost
- Oud-Zuid
- Oud-Noord
Specifying the area
Alternatives

Possible choices:

1. Compute shortest paths (pgROUTING)
2. Ask for alternatives through APIs
   a. Google Directions
   b. BING Routes
   c. OSM Openrouteservice
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Requirements:

1. Users can access through smartphones
Alternatives

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2. Free of charge
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OSM Openrouteservice API:

1. Up to 2,500 requests per day
2. Up to 3 alternatives:
   a. fastest,
   b. shortest,
   c. recommended
GPS & OSM alternatives

**OSM alternative type: shortest distance:** 1,994 km

**GPS route type: actual distance:** 2,000 km

```python
import requests

body = {"coordinates": [[4.905717, 52.359885], [4.922088, 52.37152]], "attributes": {"wayspeed": "detour", "extra_info": "["waycategory"]", "preference": "fastest", "geometry": "true"}}

headers = {
    'Accept': 'application/json, application/geo+json, application/gpx+xml, img/png; charset=utf-8',
    'Authorization': 'Bearer your_token'}

call = requests.post('https://api.openrouteservice.org/v2/directions/cycling-regular', json=body, headers=headers)

print(call.status_code, call.reason)
print(call.text)
```
Generate 3D environment
3D Buildings
Table 4.3: Statistics about the simplified network and the OSM network

<table>
<thead>
<tr>
<th>Statistics</th>
<th>OSM</th>
<th>Simplified Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of segments</td>
<td>6086</td>
<td>2701</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>26426</td>
<td>5402</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0.10566</td>
<td>9.0</td>
</tr>
<tr>
<td>Max</td>
<td>2487.01803</td>
<td>624.0</td>
</tr>
<tr>
<td>Mean</td>
<td>66.978810</td>
<td>77.80340</td>
</tr>
<tr>
<td>Median</td>
<td>32.083225</td>
<td>62.0</td>
</tr>
<tr>
<td>StdDev</td>
<td>119.4276695</td>
<td>58.72972</td>
</tr>
<tr>
<td>Minority</td>
<td>0.10966</td>
<td>9.0</td>
</tr>
<tr>
<td>Majority</td>
<td>3.38003</td>
<td>28.0</td>
</tr>
<tr>
<td>1st Quartile</td>
<td>11.78447</td>
<td>38.0</td>
</tr>
<tr>
<td>3rd Quartile</td>
<td>79.20152</td>
<td>100.0</td>
</tr>
<tr>
<td>IQR</td>
<td>67.41704</td>
<td>62.0</td>
</tr>
</tbody>
</table>
Categories of streets

Table 4.6: Categorization of the street segments based on the nth percentile.

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentile (P)</th>
<th>Lengths (m) intervals</th>
<th>Number of segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>P75</td>
<td>[5, 19]</td>
<td>145</td>
</tr>
<tr>
<td>B</td>
<td>P20</td>
<td>[19, 31]</td>
<td>411</td>
</tr>
<tr>
<td>C</td>
<td>P40</td>
<td>[34, 51]</td>
<td>550</td>
</tr>
<tr>
<td>D</td>
<td>P60</td>
<td>[53, 73]</td>
<td>518</td>
</tr>
<tr>
<td>E</td>
<td>P80</td>
<td>[73, 113]</td>
<td>549</td>
</tr>
<tr>
<td>F</td>
<td>P95</td>
<td>[113, 194]</td>
<td>408</td>
</tr>
<tr>
<td>G</td>
<td>P100</td>
<td>[194, 624]</td>
<td>136</td>
</tr>
</tbody>
</table>
Granularity

Maximum distance of visibility - 50m

Rejected:

150m
- Computational time: 45min for 50pts
- Not representative for: % sky

100m
- Computational time: 35min for 50pts
- Not representative for: % sky
Visibility analysis

Length of ray: 50m
Vertical angle: 90 degrees
Horizontal angle: 100 degrees
Resolution: 200
Visibility analysis
Metrics
2. Street Profiles
2. Street Profiles
Shape of 3D isovist

Median

Kurtosis

Standard Deviation
Aggregation on street network level

1. **Geometric mean**

Calculation of Geometric Mean for \( x_1, x_2, ..., x_n \) changing factors

\[
\prod_{i=1}^{n} x_i = \sqrt[n]{x_1 x_2 \cdots x_n}
\]

2. **Standard deviation**

3. **Mode**
Aggregation on street network level

% of visible sky

% of visible buildings

% of visible ground
Aggregation on street network level

Street profiles

1
2
3
4
5
6
7

Identified as #1

but....
Aggregation on street network level

Median

Standard deviation

Kurtosis
### Segment matching

### Aggregation methods:

1. **Standard deviation**
2. **Median**

| tripod_integer | median_sky double precision | Std.Dev_sky double precision | median_blds double precision | Std.Dev_blds double precision | median_grd double precision | Std.Dev_grd double precision | median_kurtosis double precision | Std.Dev_kurtosis double precision | median_median double precision | Std.Dev_median double precision | median_stdDev double precision | Std.Dev_stdDev double precision | category_integer |
|----------------|-----------------------------|-------------------------------|-----------------------------|-------------------------------|----------------------------|-----------------------------|--------------------------------|--------------------------------|-------------------------------|-----------------------------|-----------------------------|------------------------------|-----------------------------|-----------------------------|
| 56355513       | 37.64053093                 | 9.81262743                   | 13.00308075                | 12.79632207                  | 47.18268695                  | 5.32894767                  | 0.11953996                    | 0.90294706                    | 21.16335174                  | 11.85934794                  | 21.00282264                 | 1.753844923                  | 2                           |
| 59424403       | 29.84223853                 | 11.82134499                  | 22.54545856                | 15.80861606                  | 44.70199862                  | 2.48589657                  | 0.24490063                    | 0.457368693                   | 12.15415634                  | 11.26872269                  | 20.39363836                 | 2.348997148                   | 5                           |
| 591512884      | 33.85011556                 | 11.38745835                  | 17.2268856                  | 16.54079242                  | 44.6577443                  | 6.651303594                  | 0.22673725                    | 1.382636793                   | 17.27140157                  | 9.768459815                  | 20.72929994                 | 2.125045794                  | 2                           |
| 591590491      | 30.32346469                 | 9.707456108                  | 23.56762264                | 10.00460894                  | 44.35916673                  | 2.65330954                  | 0.31072912                    | 0.74810825                   | 12.8372377                  | 6.17866858                 | 20.32278367                 | 2.577535443                  | 1                           |
| 592027612      | 34.76090946                 | 11.1384614                   | 18.11236513                | 13.98469113                  | 46.04947238                  | 5.43157797                  | 0.14065556                    | 0.45741839                   | 19.76676996                 | 11.89241076                 | 20.76082419                 | 1.942725989                  | 2                           |
| 592384567      | 32.64939025                 | 8.581018165                 | 20.65952309                | 11.80300989                  | 45.42860158                  | 5.70634237                  | 0.27137056                    | 0.43306591                   | 14.46335789                 | 7.01514148                  | 20.37868048                 | 1.767975144                  | 5                           |
| 593403756      | 32.93479903                 | 9.38123872                   | 21.08872122                | 13.046276                  | 46.04947238                  | 5.912795894                | 0.18597768                     | 0.432267613                   | 14.13435302                 | 7.950560979                 | 20.56388902                 | 1.923901482                  | 2                           |
| 595695229      | 31.4810827                 | 10.21051027                  | 22.75613533                | 11.78074173                | 44.55569599                  | 3.39904982                  | 0.22004093                    | 2.42210808                   | 12.77540654                 | 8.969963649                 | 20.3577974                  | 2.672475478                  | 2                           |
| 596424426      | 31.12088161                 | 8.031986122                  | 21.48996393                | 11.22085627                | 44.81983517                  | 2.227508311                 | 0.20310088                    | 0.319122422                   | 12.45802433                 | 5.175462534                 | 20.44812221                 | 1.968024911                  | 3                           |
Results
Results – Qualitative analyses
Results – ANOVA analyses

Tukey’s and Games-Howell post hoc tests

Coding types of routes:
1: GPS route - 2: Fastest route - 3: Shortest route - 4: Recommended route

Dependent variables:
- StDev of Sky,
- StDev of Buildings,
- StDev of Ground,
- StDev of Standard deviation of length of rays,
- StDev of ratio buildings/sky,
- StDev of ratio buildings/ground, and
- Distance
Results – ANOVA analyses

- **Distance**
  - Cyclists are following longer routes

- **StDev of StDev**
  - Cyclists are following routes with different street profiles

- **StDev of Median**
  - Cyclists are following non-homogeneous routes
Results – ANOVA analyses

Variations in visible sky

Cyclists are following routes with more variations in the visible sky

Variations in visible buildings

Cyclists are following routes with more variations in the visible buildings
Cyclists are following routes with more variations in the ratio buildings:sky

Cyclists are following routes with more variations in the ratio buildings:ground
Conclusion & Future research
Cyclists don't follow the shortest or fastest routes but seek for variations in the built environment and non-homogeneous routes.

- Planning of cyclists’ accessibility to the street network not limited to fastest and shortest routes
- In busy neighborhoods, cyclists are following secondary streets even when bicycle lanes do not exist
- Variations of buildings is an important difference but when combined with sky or ground
- Ground element gives a non-significant difference - Street infrastructure (Requires higher level of detail?)
Conclusion - Methodology

Methodology succeed to capture the 3D environment of the routes and add value to the 2D methodology

Openrouteservice API suggestions are limited to streets with bicycle lanes

Threshold of merging route or centreline leads to misinformation (recommended routes)

Aggregated street profiles did not succeed to capture the 3D environment but have potentials

Statistical Analysis - Did not capture connection between the metrics

Definition of streets’ categories leads to overlaps

Good performance of Rhino but slower when using Python and rerun of visibility analyses at streets with a lot of information
Cyclists prefer to travel through routes with variations in the built environment without considering travel time/distance.

The 3D isovist methodology captures the visible views and add value to Space syntax methodology.

It can help to define design guidelines and give a deeper insight of the cyclists’ route choices.
Future research

Investigation of application in more GPS routes and study areas

Sensitivity analysis - Is the centreline the appropriate way to explore the visibility of a cyclist?

Details to the ground element - Define water, greenery

Landmarks and gravity points should be included

Investigation of decision points (intersections) and turns

Application of suggested methodology - Visibility Graphs
Thank you! :)

Complete methodology

RQ: To what extent do the directly visible views of the urban environment influence the route choices of cyclists and how can these views be measured?