

Inverse procedural Street Modelling: from interactive to automatic reconstruction

Phd Defense : Rémi Cura, 2016/09/12

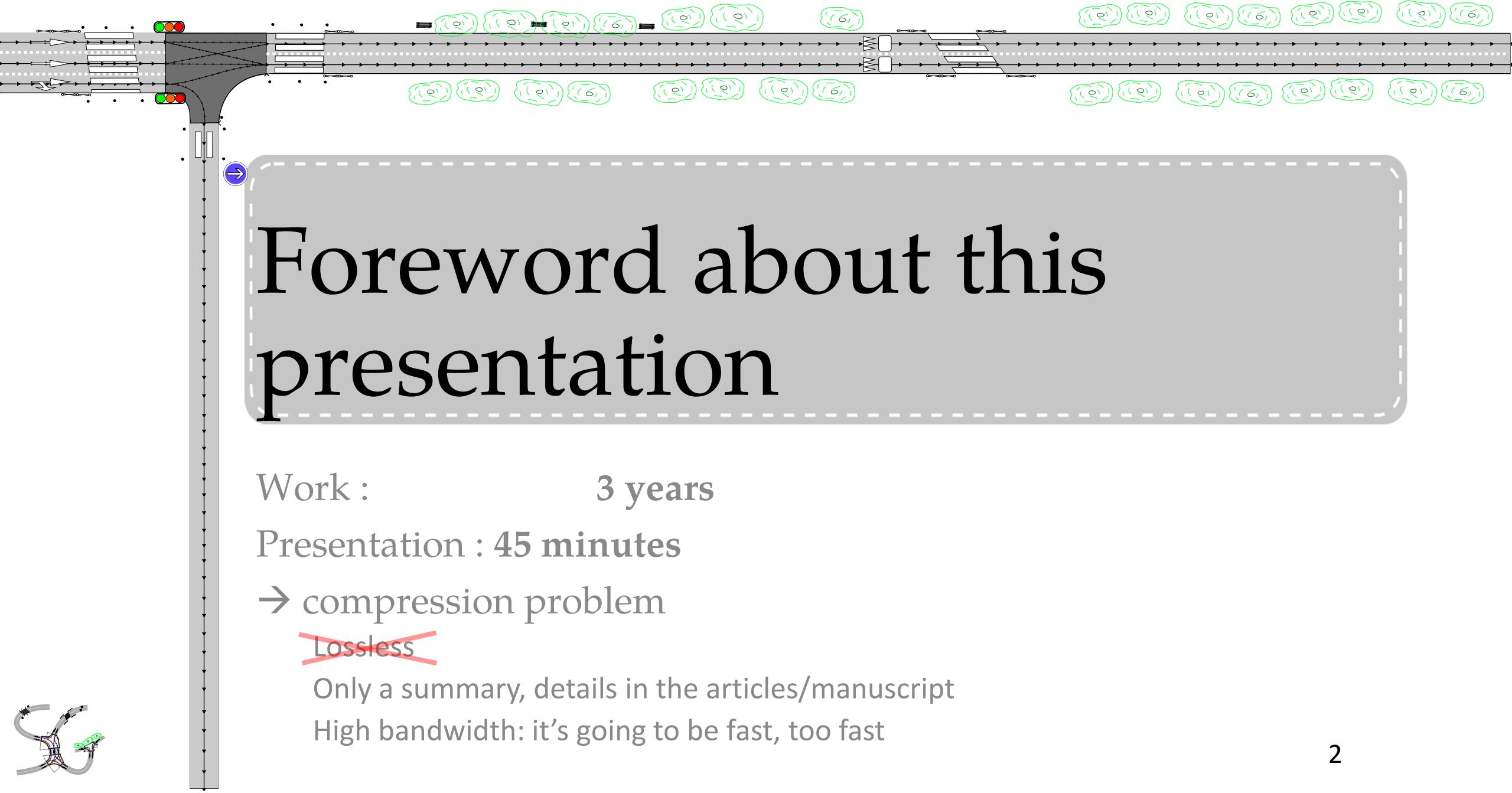
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École Doctorale Mathématiques et Sciences et Technologies
de l'Information et de la Communication (MSTIC)*

Jury:

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Pr. Peter Van Oosterom (TUDelft)
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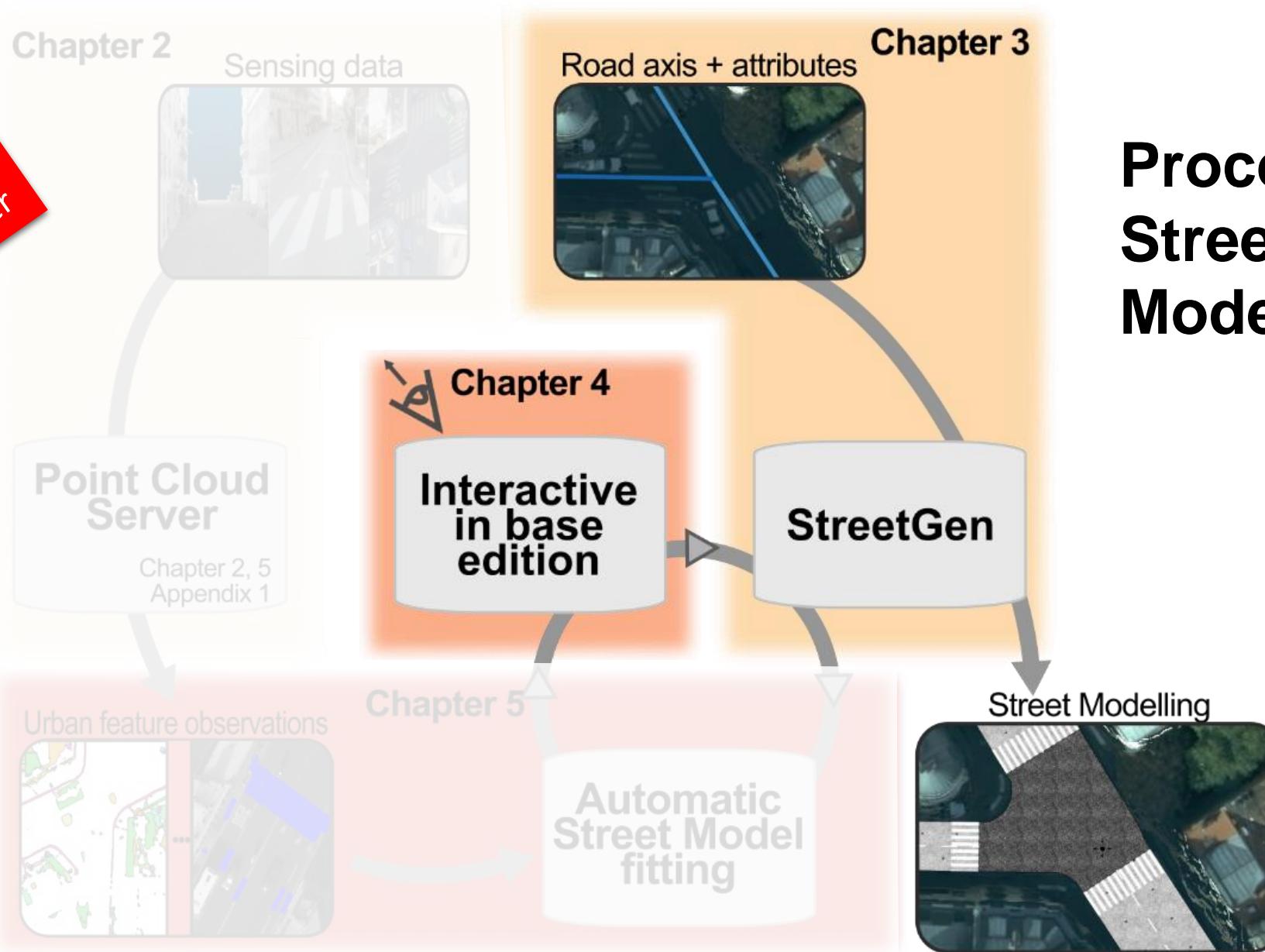
Dr. Julien Perret (IGN)
Dr. Nicolas Paparoditis (IGN)
Dr. Kevin Lyvan (Thales)





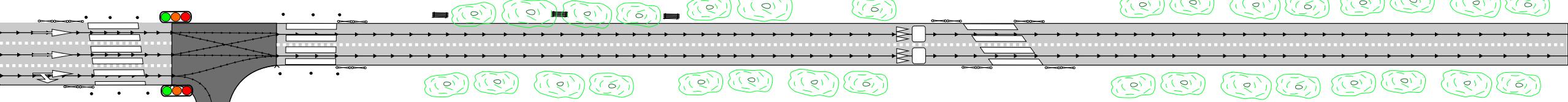
Abstract

Todo : replace chapter by presentation order



Procedural Street Modelling

PLAN



Introduction: Why model streets?

State of the art: How to model streets?

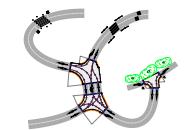
StreetGen :

- Generating best guess streets
- Editing streets (in-base)
- Fitting the street model

Data for observation:

Point Cloud Server

Conclusion (5')



width= 8; lane= 3

width= 6; lane= 2

Intro

State of the Art

StreetGen

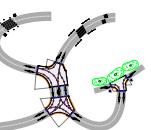
Streets

Interaction

Automation

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Conclusion



Introduction

Why model streets?

Usages for street model

Introduction: Streets are important

width= 8; lane= 3

width= 6; lane= 2

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width= 4; lane= 1

- Cities are important places
 - Many people live in it
 - World : 50% in urban area.
 - France : 80%
 - Concentrate people/power/usages/issues
- Streets are important in cities
 - In paris, streets area > building area
 - Streets = medium between people/occupations

Introduction: having a model is important

width= 8; lane= 3

width= 6; lane= 2

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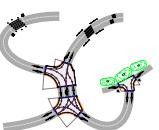
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width= 4; lane= 1

- Modelling the streets
 - Visualisation (map / 3D model)
 - Simulation
 - Analysis
 - ...
- Why would we want an accurate, structured, up to date map of streets?
 - Mapping = maps are classical control/management tools
 - Map war for South America (Madrid, 1750)
 - Mapping = visualising: very helpful for human
 - (demo th. Pythagore visual vs math)



width= 8; lane= 3

width= 6; lane= 2

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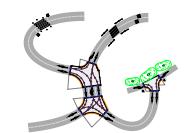
Conclusion

width= 4; lane= 1

Introduction

Why model streets?

Usages for street model



Introduction: usages for street model

width= 8; lane= 3

width= 6; lane= 2

- Cities are actually carefully managed
 - Paris : 100' of people, one dedicated engineer school
 - Requires data (precise, up to date)
 - Visualisation (map / 3D model)
 - Decision making
 - Consultation / communication
 - Simulation
 - Traffic / pollution / noise / parkings ...
 - Analysis (past/present/planning)

width= 4; lane= 1

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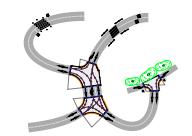
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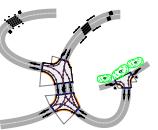
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Introduction: usages for city model

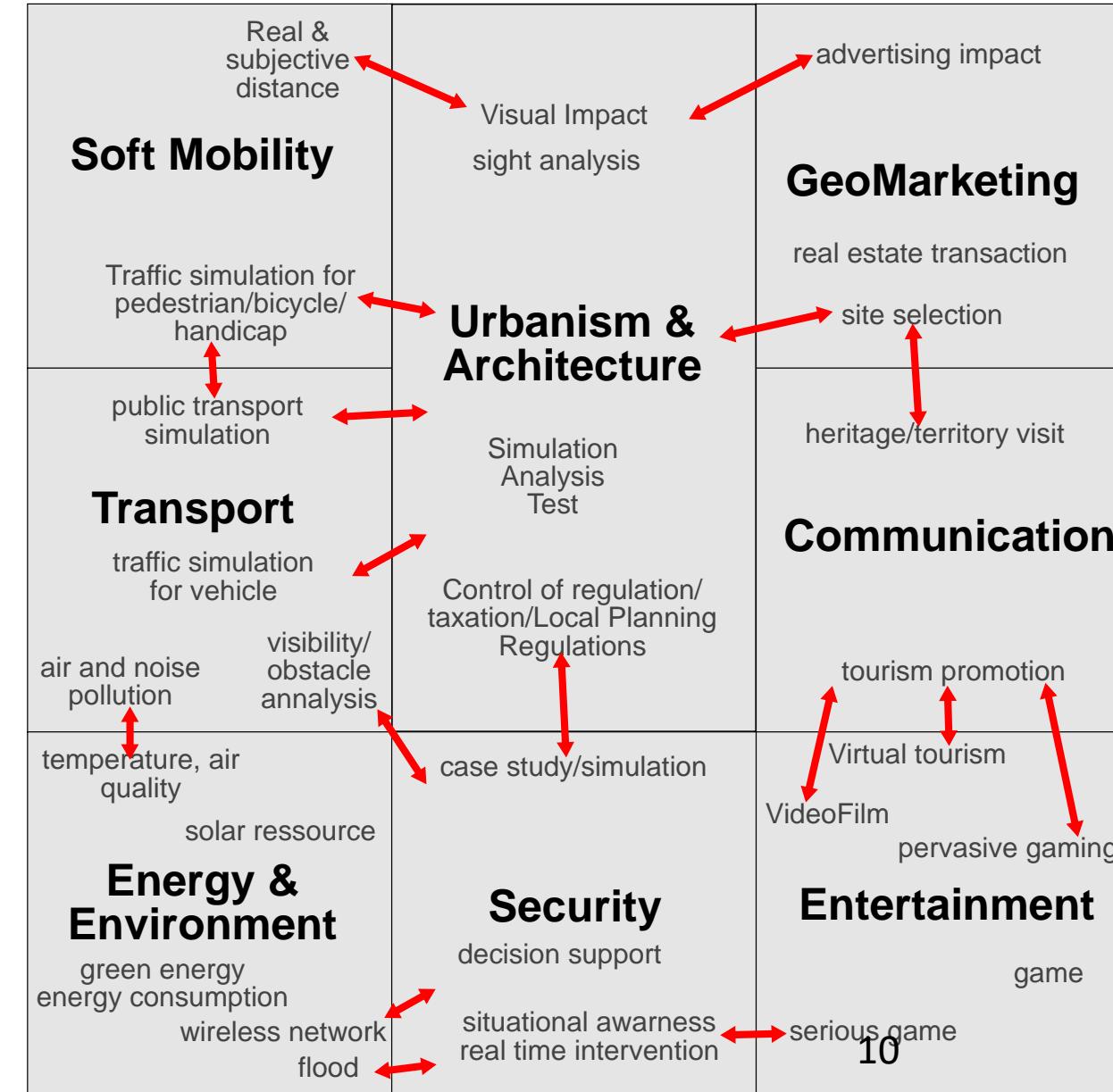
- Street model ⊂ city model
- Many usages for a city model

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width= 6; lane= 2

width= 8; lane= 3



edge_id=15; next_l=16
end_node=3 ...

edge_id=16; next_l=17
start_node=4 ...

edge_id=17; next_l=16
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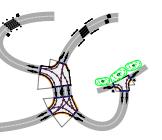
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Conclusion

State of the art

Modelling street, why is it hard?

Existing models



State of the art: modelling street is hard

edge_id=15; next_l=16
end_node=3 ...

edge_id=16; next_l=17
start_node=4 ...

- Even 'regular' streets are hard to model
 - Complex (even for human)
 - Traffic
 - Organised
 - Hard to sense

edge_id=17; next_l=16
start_node=4 ...

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State of the art: modelling street is hard

edge_id= 15; next_l= 16
start_node= 3 ...

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- Streets are complex

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edge_id= 17; next_l= 16
start_node= 4 ...



State of the art: modelling street is hard

edge_id= 15; next_l= 16
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edge_id= 16; next_l= 17
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- Streets are complex

edge_id= 17; next_l= 16
start_node= 4 ...



State of the art: modelling street is hard

edge_id= 15; next_l= 16
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- Streets are complex

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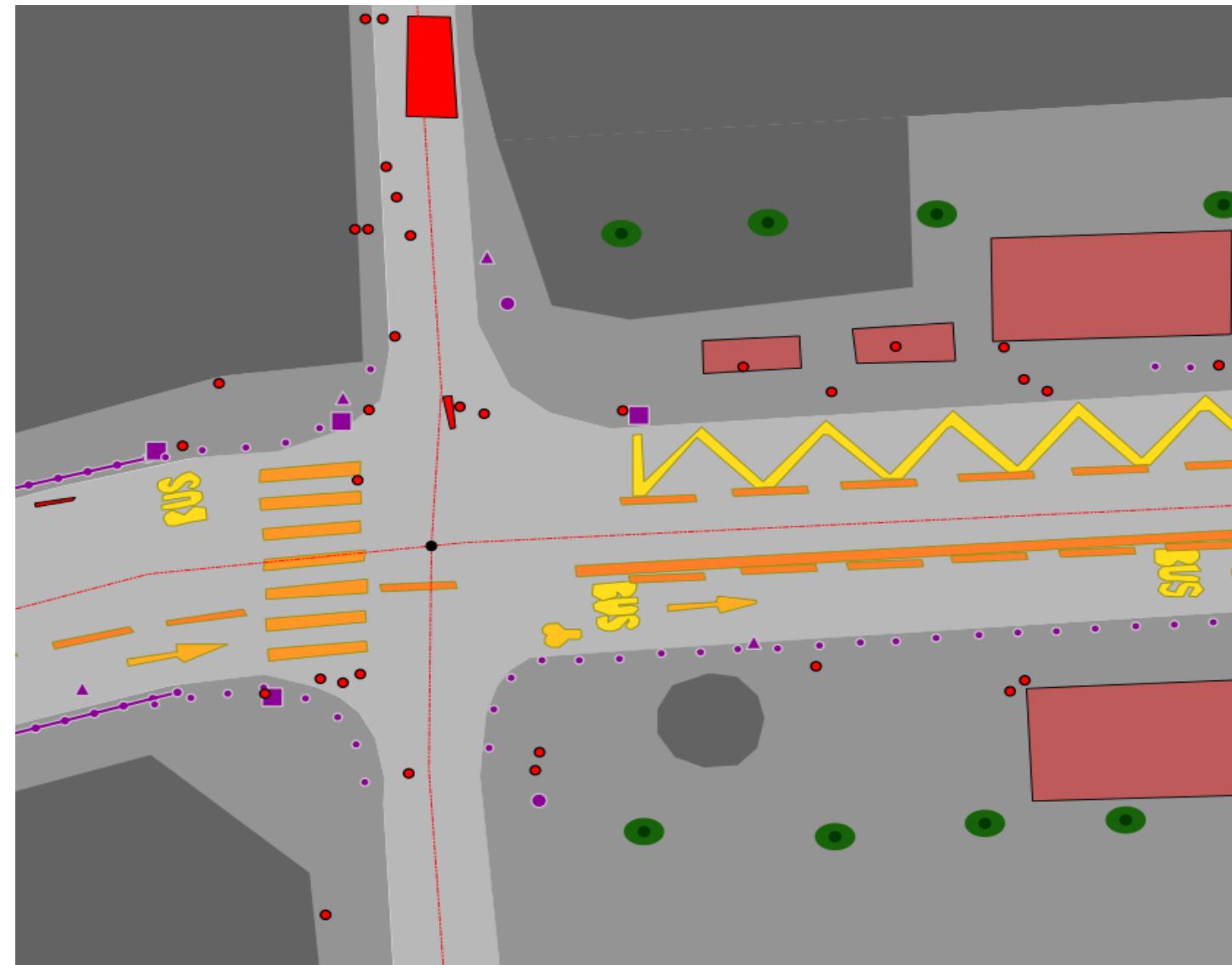
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edge_id= 17; next_l= 16



road_network

intersection node

road axe

vegetation

tree

mobility

pedestrian

bicycle

vehicle

bus_stop

metro

bus

metro

Signage

bu

ve

fl

pp

ma

street furniture

barrier

bollard

traffic_light

furniture

public_light

WC

land use

road

sidewalk

building

kiosque

terrace

State of the art: modelling street is hard

edge_id= 15; next_l= 16
start_node= 4 ...
end_node= 3 ...

- Streets are a medium supporting all type of traffic

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State of the art: modelling street is hard

edge_id= 15; next_l= 16
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edge_id= 16; next_l= 17
start_node= 4 ...

- Streets are organised (symmetry, hierarchy, part of network ...)

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State of the art: modelling street is hard

edge_id=15; next_l=16
end_node=3 ...

- Streets are hard to sense
 - Manual : millions of objects
 - Automatic :
 - high occlusion
 - Small details are essential (curb)



edge_id=17; next_l=16
start_node=4 ...



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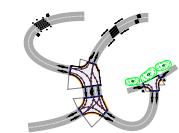
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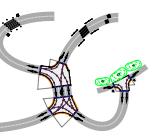
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Modelling street, why is it hard?

Existing models



State of the art: Existing models

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edge_id=17; next_l=16
start_node=4 ...

- What should be modelled?
 - Street precise geometry (roadway/ sidewalk / ...)
 - Street road as part of whole network (= traffic info)
 - Street organisation
 - Street objects
 - Street objects relations
 - Material/visual aspects ...

State of the art: Existing models

edge_id=15; next_l=16
end_node=3 ...

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start_node=4 ...

- Everybody is interested by different street aspects
 - **GIS** : road as center line + buffer
 - **Traffic simulation** : road network / pedestrian space
 - **Computer graphics** : nice 3D roads blending with surroundings
 - **Procedural city modelling** : road network as start for procedural city
 - **Remote Sensing** : mostly road surface and markings
 - **driving simulator** : intersection
 - **Automotive industrial** : roadway detailed characteristics
 - ...

edge_id=17; next_l=16
start_node=4 ...

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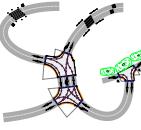
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State of the art: Existing models

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Wilkie2012
Kuntzsch2015

Wang2015
Despine2011

Guo2015
Montoya-Zegarra2014
Boyko2011
Serna2015

Gallin2011
Chen2008

CityGML
Road XML
Open Drive

**GIS
modelling**

**simulation
modelling**

**data-driven
modelling**

road network

street model

roadway

**procedural
modelling**

road/lane

**whole system
modelling**

State of the art: Existing models

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- Whole system modelling
 - City GML : for city, but contains a road module
 - Road XML : oriented for traffic simulation
 - Open Drive : high geometric details

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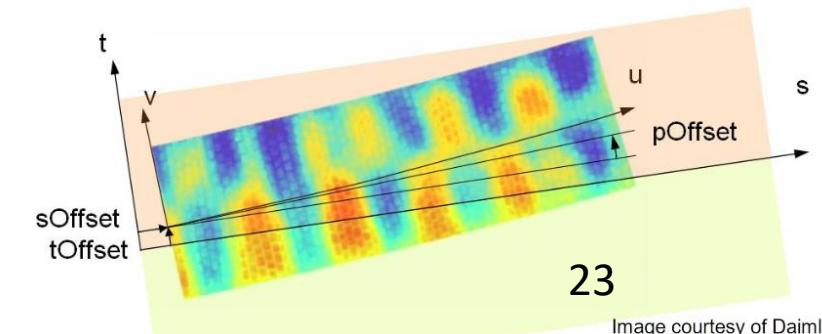
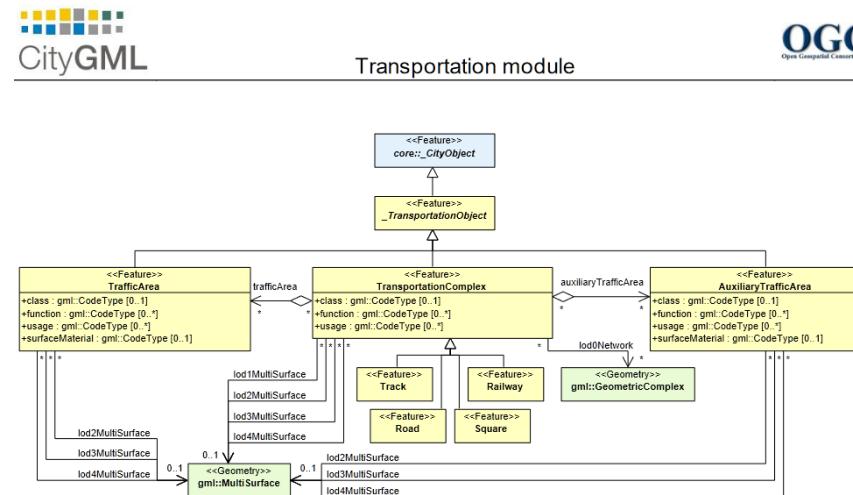


Image courtesy of Daimler AG

State of the art: Existing models

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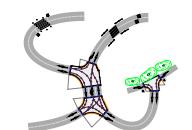
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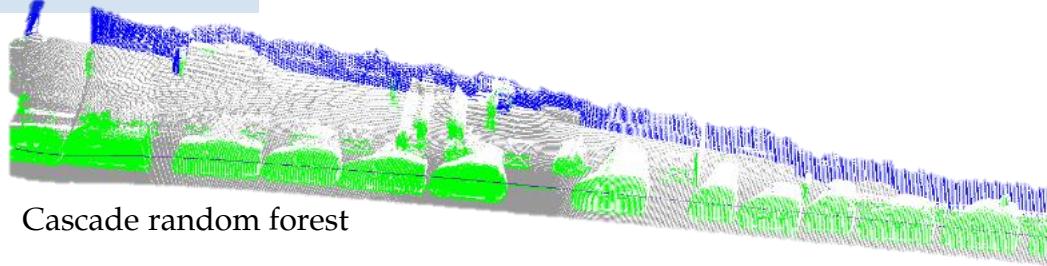
- Data-driven modelling
 - From image/lidar

Guo2015



Extraction, raster, template matching

Serna2015



Boyko2011

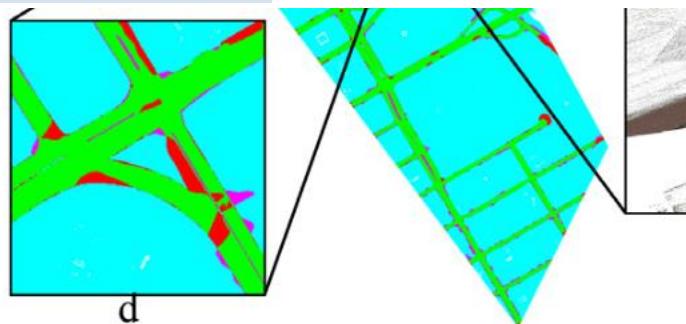
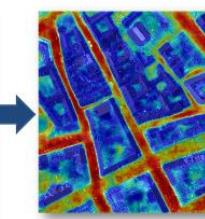


Fig. 9. Classification error map.

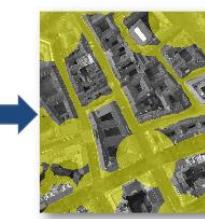
Fitting + active contour



Road likelihoods
(Section 3.2)

Classif + Context + CRF

Montoya-Zegarra2014



State of the art: Existing models

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- Data-driven modelling
 - From aerial imgs

Todo : detailed ref for
remote sensing from
images

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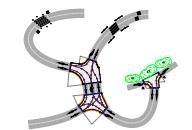
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- GIS-based modelling

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Kuntzsch2015



Street segment KDE, intersection with RJ-MCMC

Wilkie2012



Turning radius, network of lane, simulation

State of the art: Existing models

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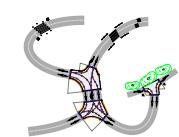
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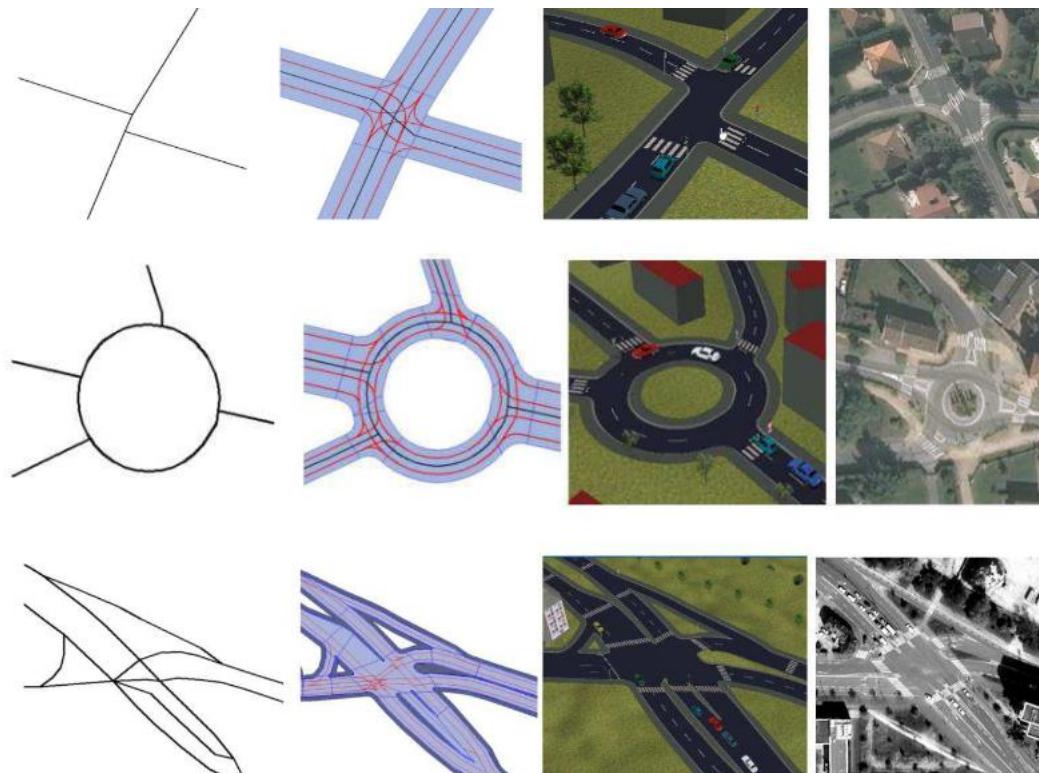
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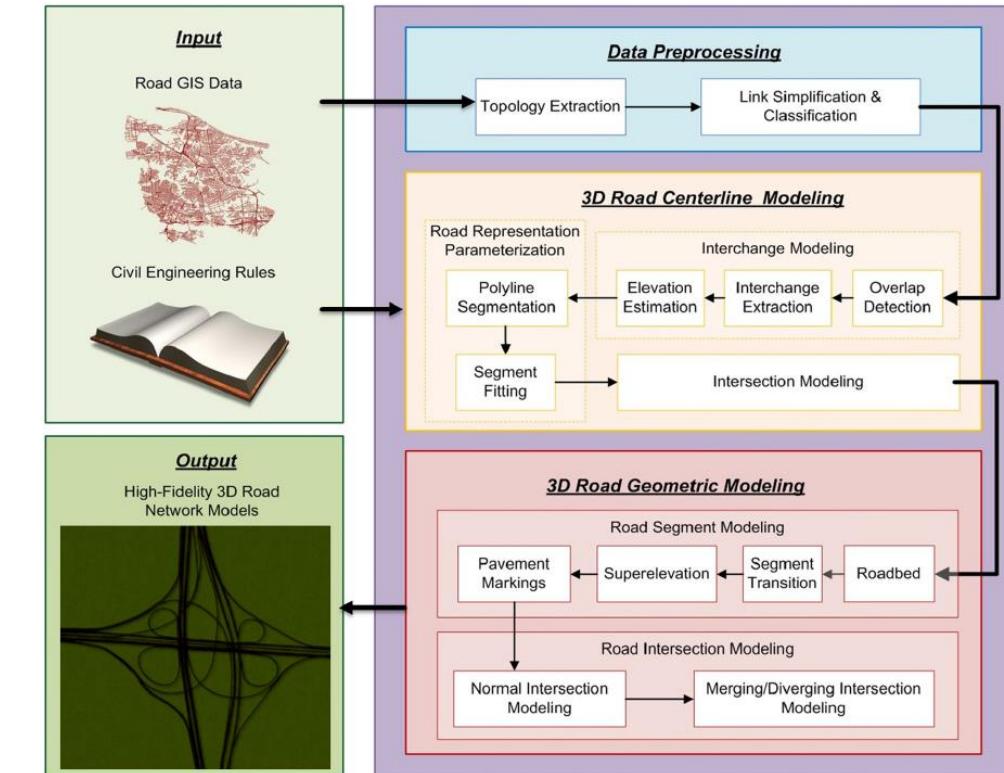
- Simulation-based modelling

Despine2011



Network from data, guessing lane, intersection by continuity, 3D generation

Wang2015



State of the art: Existing models

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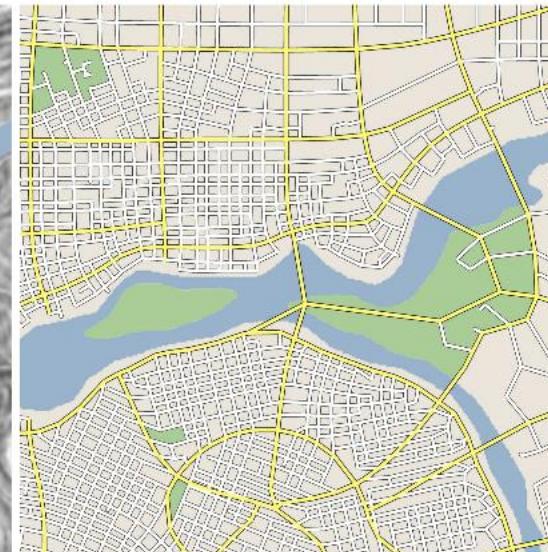
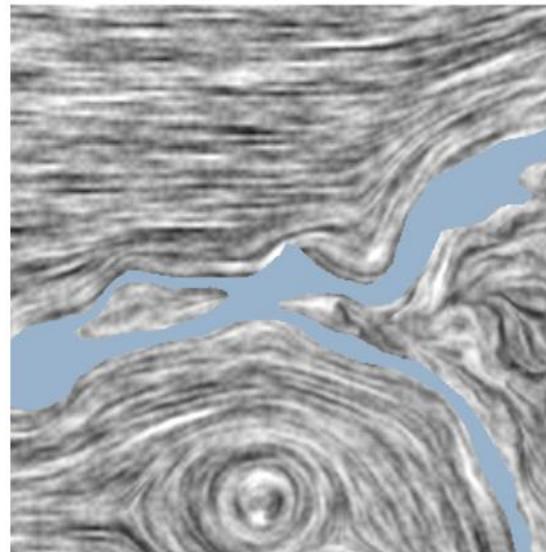
- Procedural modelling

Gallin2011



Terrain, graph : shortest path and merging,
procedural generation

Chen2008



Tensor, stream line, grammar

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StreetGen : generate streets

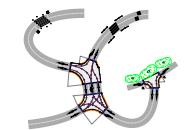
Design Principle

Kinematic hypothesis

Road surface

Traffic support

Street objects



StreetGen : design principle

edge_id= 15; next_l= 16
end_node= 3 ...

edge_id= 16; next_l= 17
start_node= 4 ...

edge_id= 17; next_l= 16
start_node= 4 ...

- To Design = to compromise
- Goals?
 - Model streets of whole Paris (scale, robustness)
 - Work with limited GIS data (best guess)
 - Model used for various outputs (analysis/ 3D visu / traffic simulation...)
 - Multi-user editing
- Our approach:
 - Limited data : based on road axis, use simple kinematic hypothesis
 - Scaling & multi-user : use a RDBMS
 - Coherent structured model : use a RDBMS

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StreetGen : design principle

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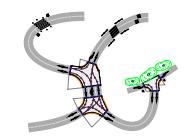
Automation

P.C. Server

Conclusion

edge_id= 17; next_l= 16
start_node= 4 ...

- Not a model for all streets, but a model for most of streets
- 3 observations on streets
 - Structured by street axis
 - 2 type of parts : morphologically constant or varying
 - Adapted to vehicle traffic
- Kinematic hypothesis :
 - Allows to rough out a road model
- Scaling/multi-user/GIS data → use a RDBMS



StreetGen : graphical abstract

edge_id= 15; next_l= 16
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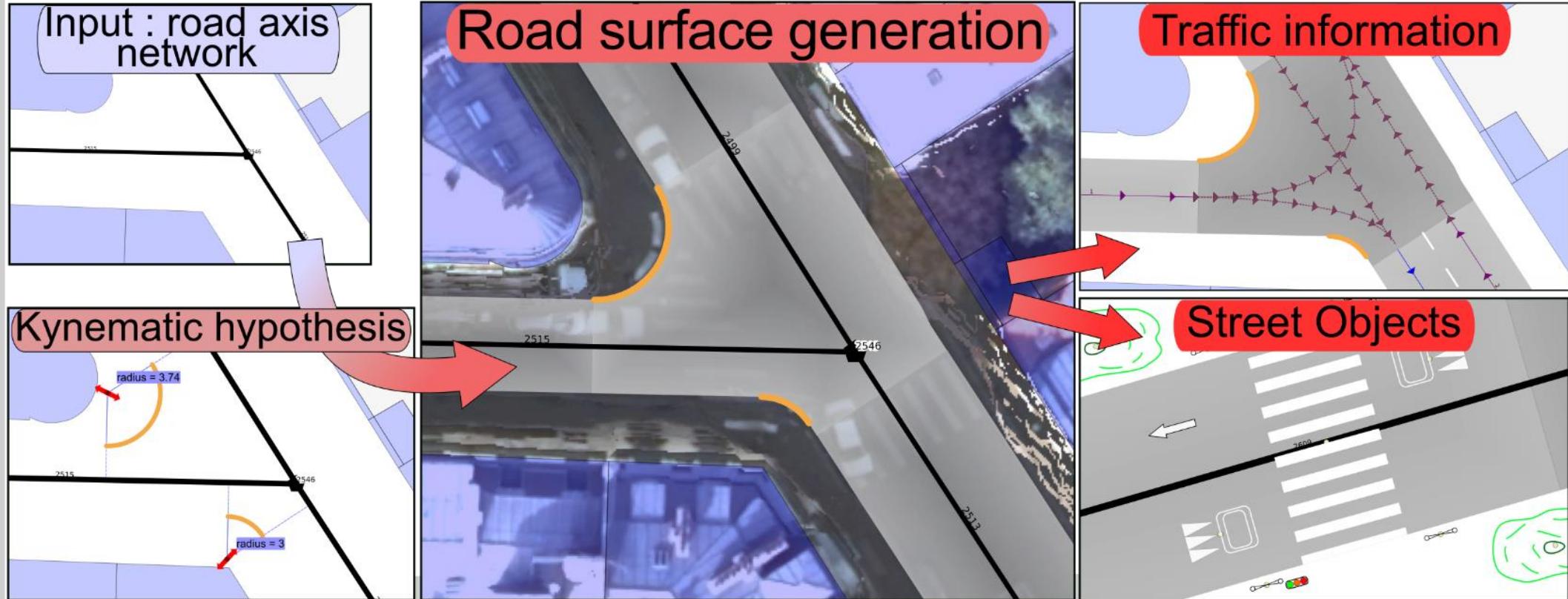
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SG

StreetGen graphical abstract ↗



database server

StreetGen : design principle

edge_id= 15; next_l= 16
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- StreetGen road model

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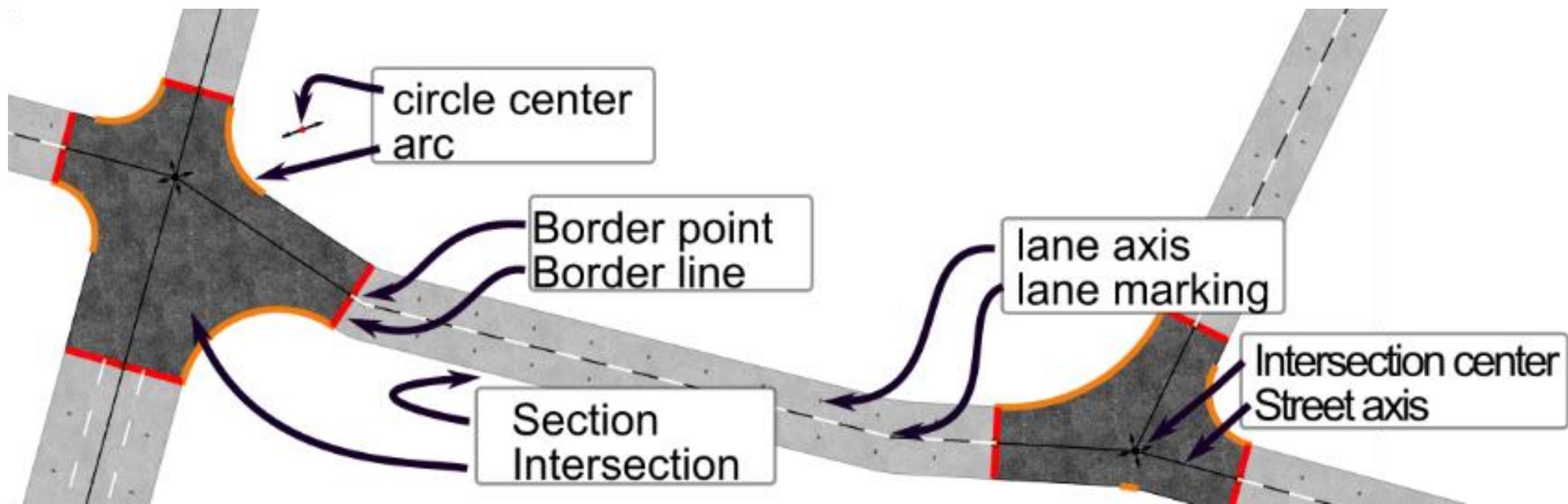
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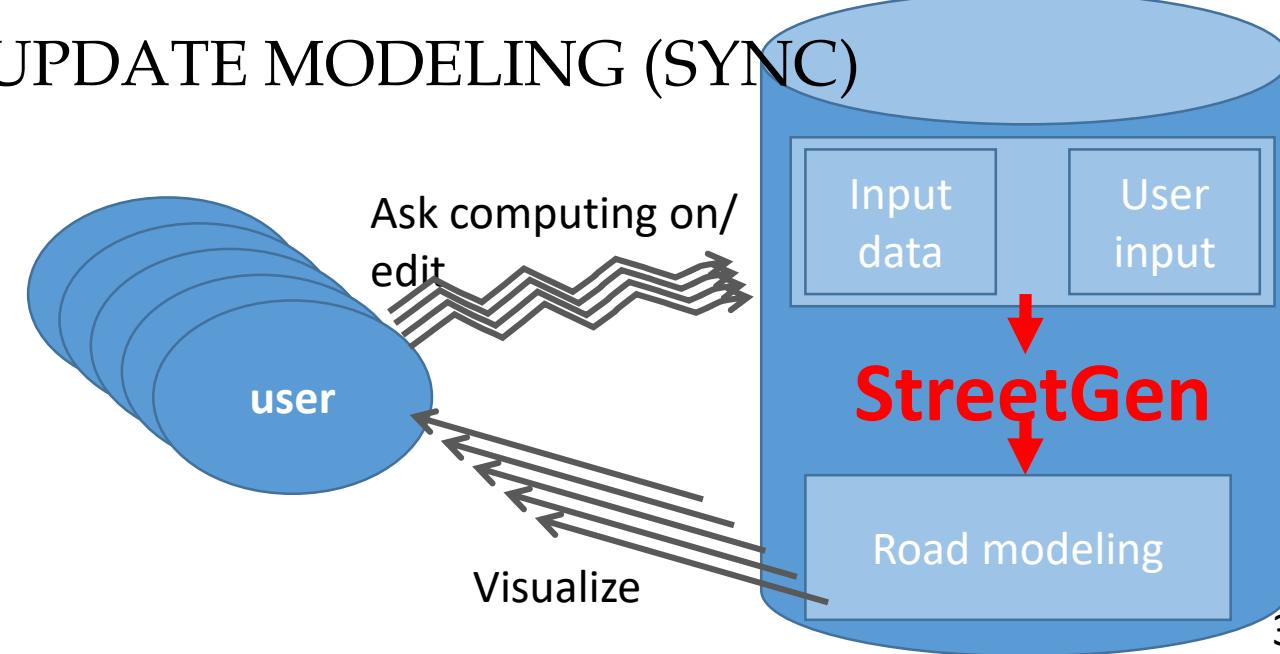
StreetGen : design principle

edge_id= 15; next_l= 16
end_node= 3 ...

How to deal with several users?
Use a RDBMS !

- ~~Read file , process, write results in a file~~
- RDBMS : made to abstract & secure data

UPDATE MODELING (SYNC)



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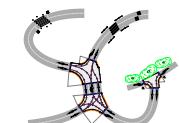
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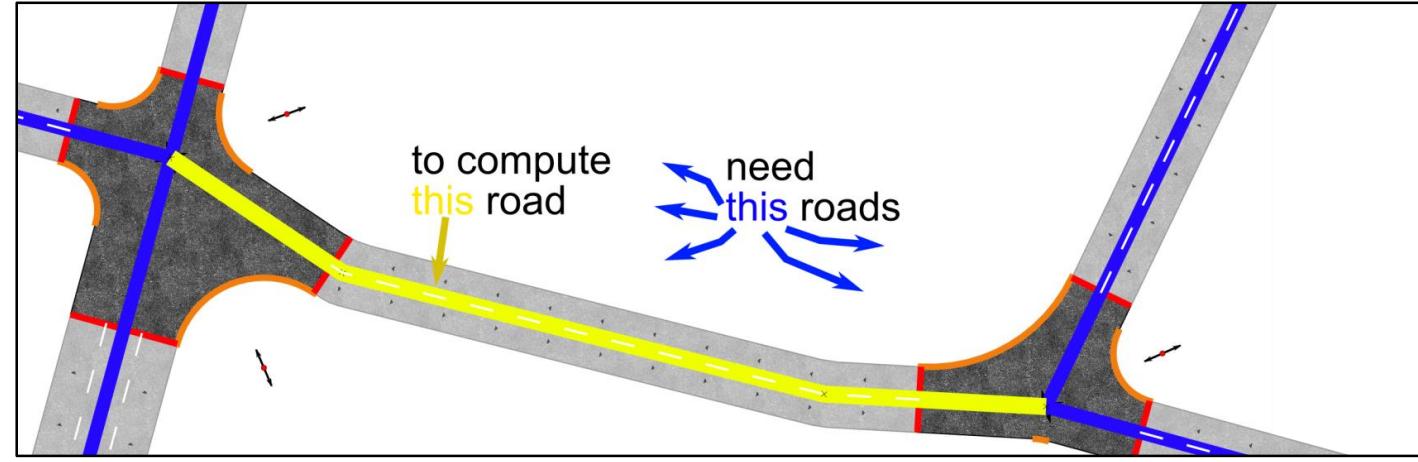


StreetGen : design principle

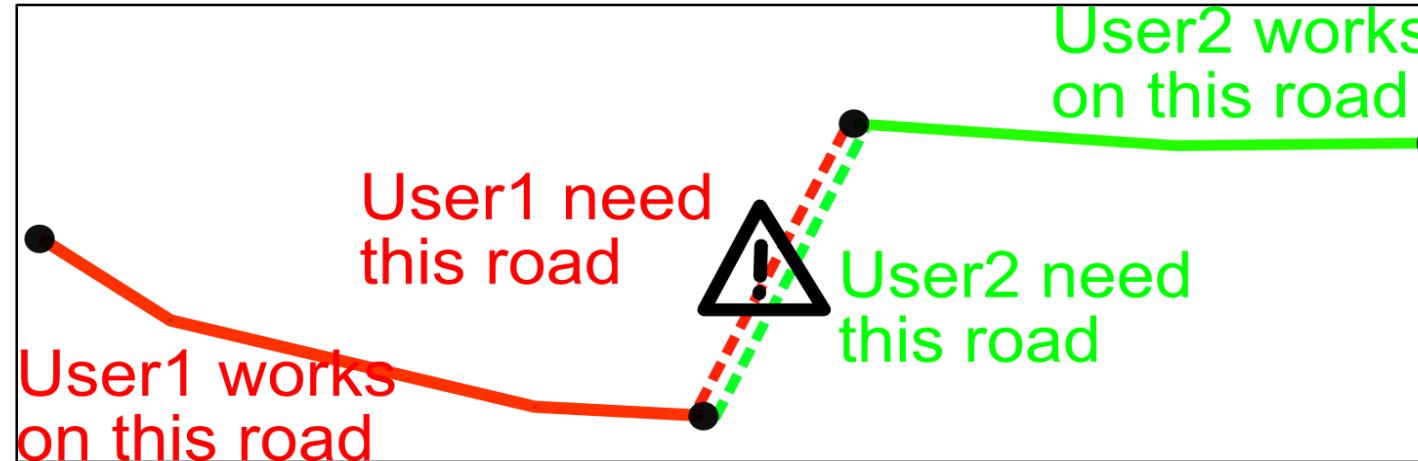
edge_id= 15; next_l= 16
end_node= 3 ...

- Need 1-neighbourhood to compute a street

edge_id= 17; next_l= 16
start_node= 4 ...



- May be computed simultaneously



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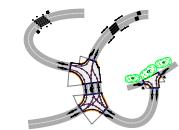
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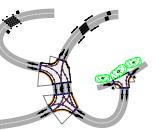
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Kinematic hypothesis
Road surface
Traffic support
Street objects



StreetGen : Kinematic hypothesis

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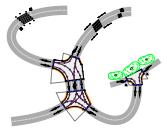
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edge_id= 17; next_l= 16
start_node= 4 ...

- Hypothesis

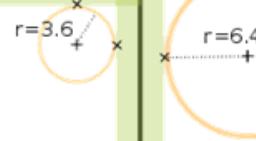
- road border is defined by a vehicle driving along it at a given speed, while making comfortable turns.

- Street type → vehicle speed
 - Vehicle speed → turning radius
 - Turning radius → road surface



StreetGen : Kinematic hypothesis

edge id=15; next_l=16
end_node=3 ...



- Illustrations :

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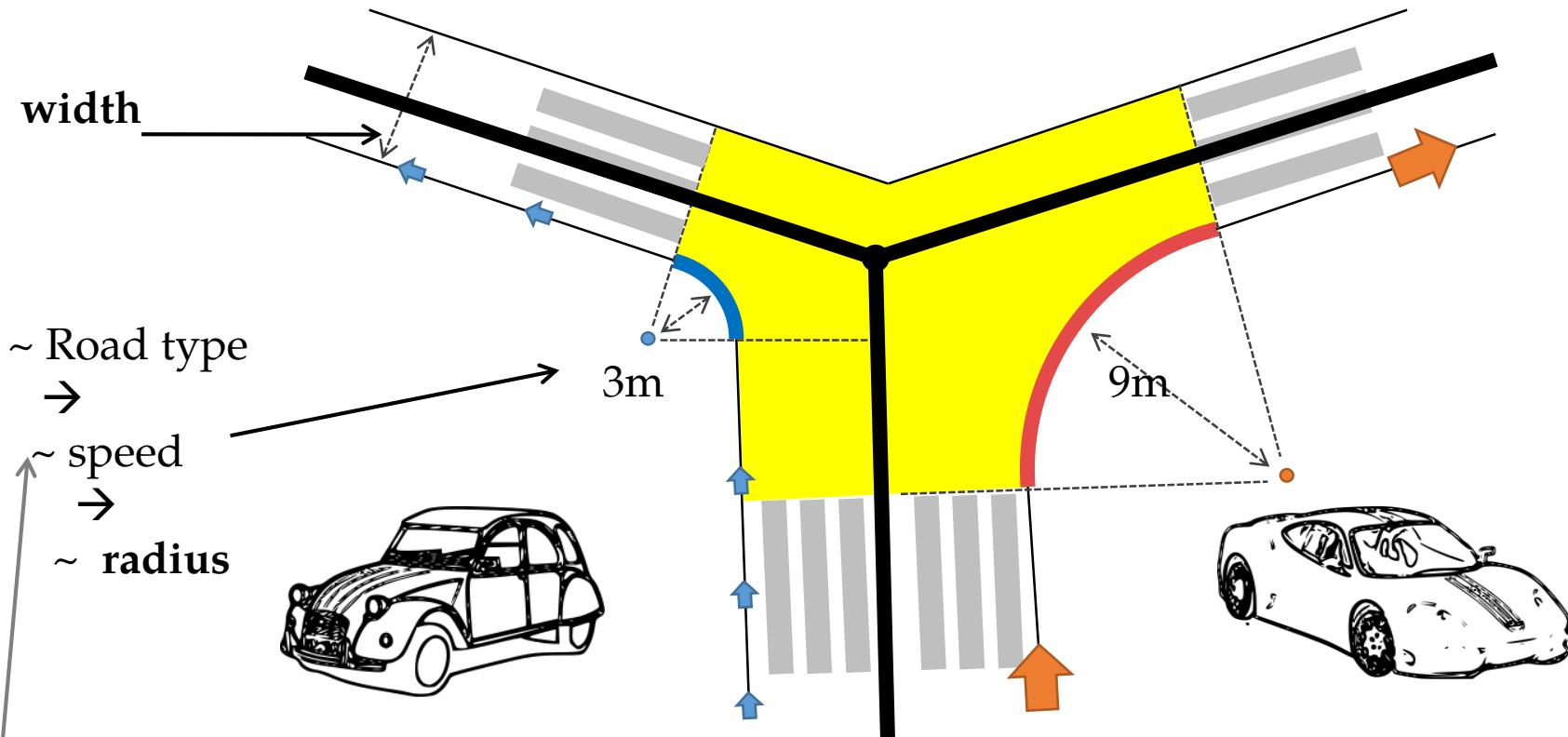
Streets

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StreetGen : Kinematic hypothesis

edge id=15; next_l=16
end_node=3 ...

r=3.6
r=6.4

edge_id=17; next_l=16
start_node=4 ...

- Various radius in Paris

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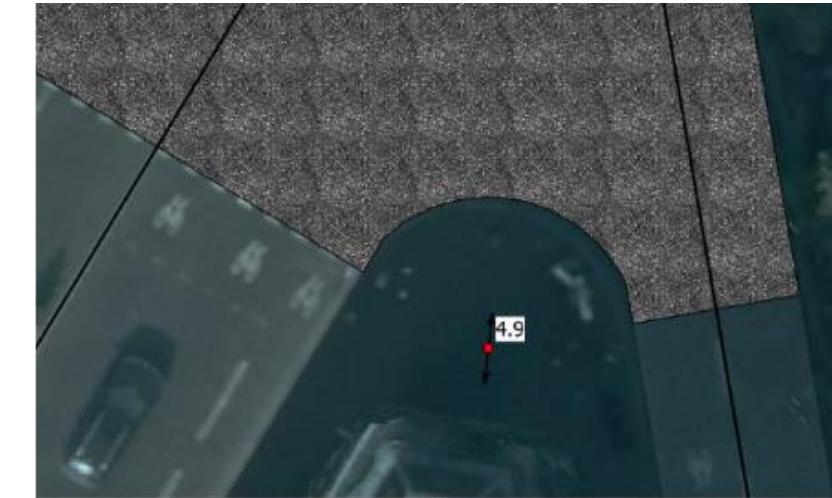
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StreetGen : Kinematic hypothesis

edge id=15; next_l=16
end_node=3 ...

$r=3.6$
 $r=6.4$

edge id=16; next_l=17
start_node=4 ...

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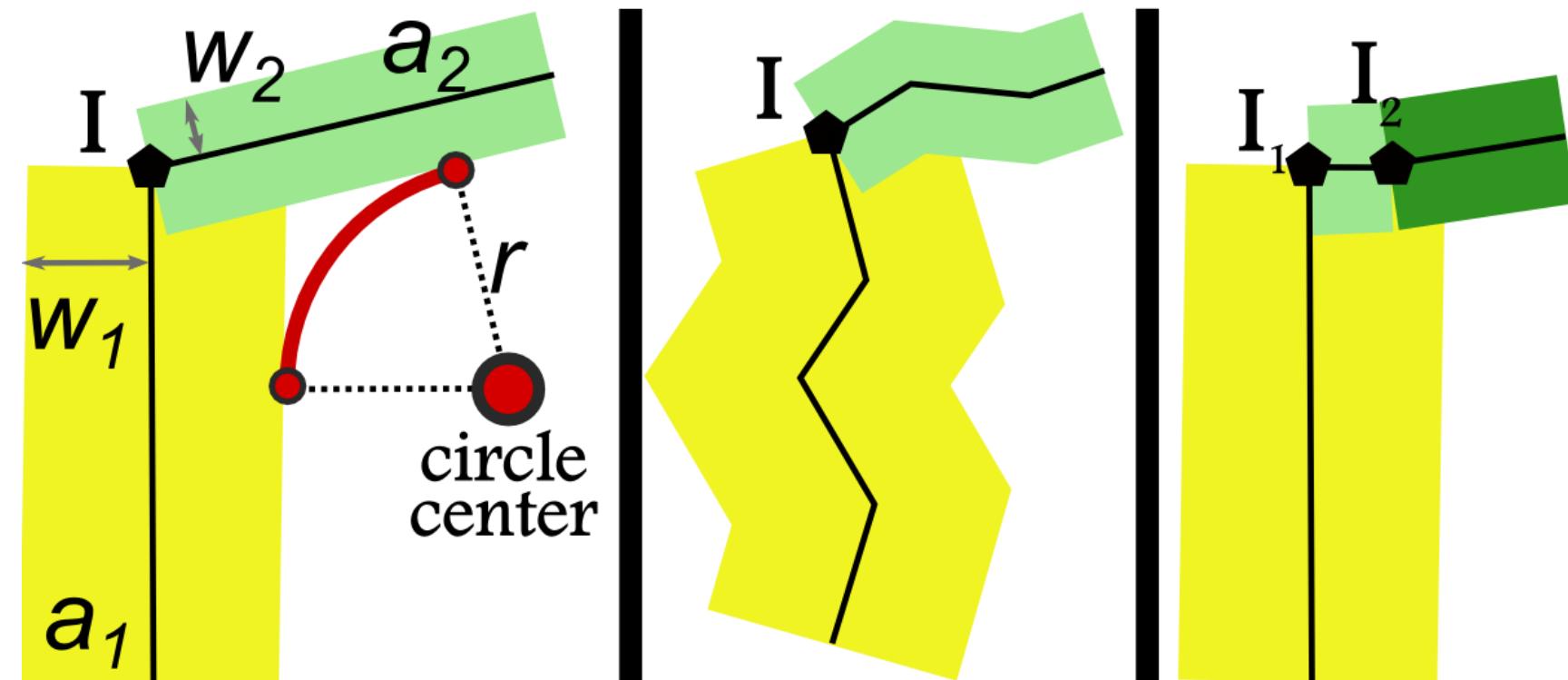
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- We have road axis, road width
 - How to compute circle center and arcs?
 - ~~analytical computing (vector, angle) ?~~



StreetGen : Kinematic hypothesis

edge id=15; next_l=16
end_node=3 ...

\bullet t

edge id=16; next_l=17
start_node=4 ...

r=3.6

r=6.4

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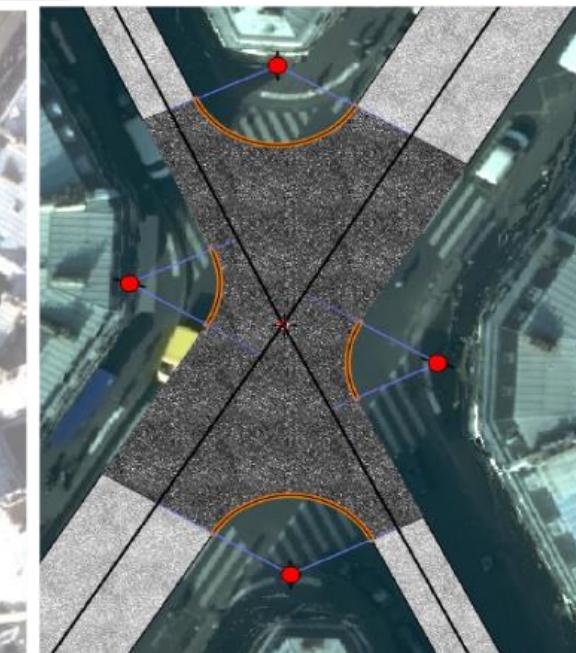
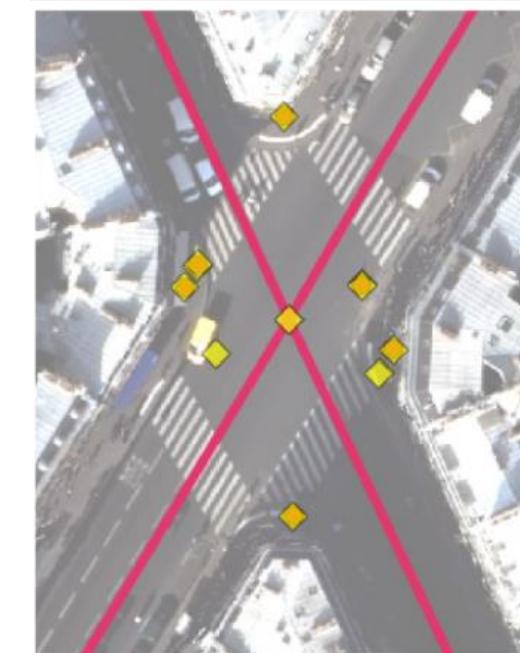
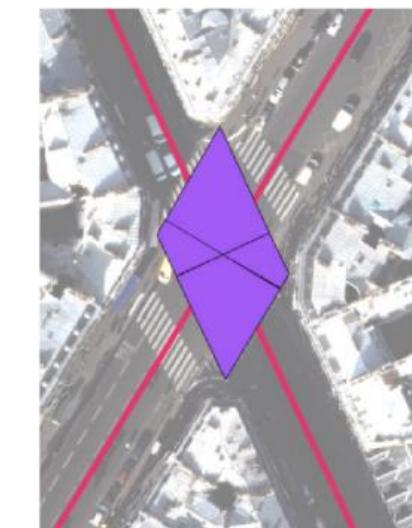
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edge id=15; next_l=16
end_node=3 ...

edge id=16; next_l=17
start_node=4 ...

r=3.6
+
x

r=6.4
+
x

edge_id=17; next_l=16
start_node=4 ...

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StreetGen : generate streets

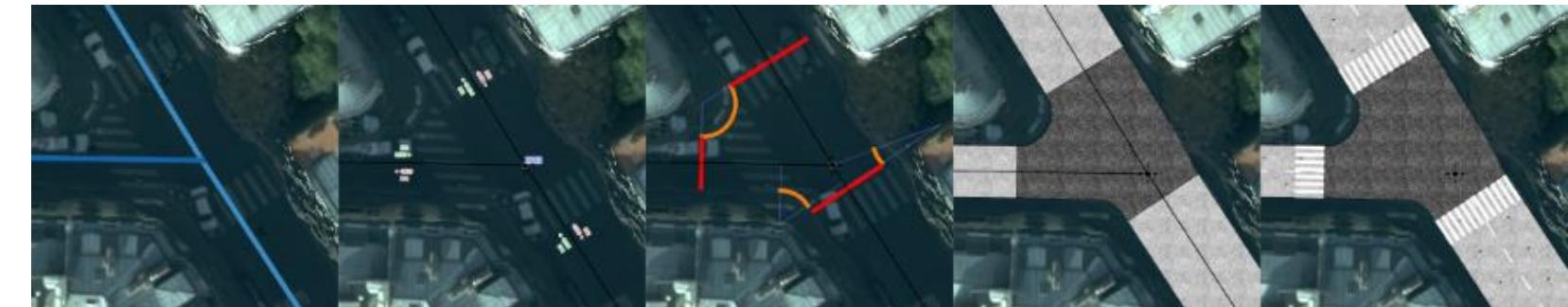
Design Principle

Kinematic hypothesis

Road surface

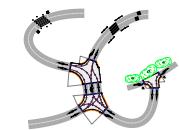
Traffic support

Street objects



StreetGen : Road surface

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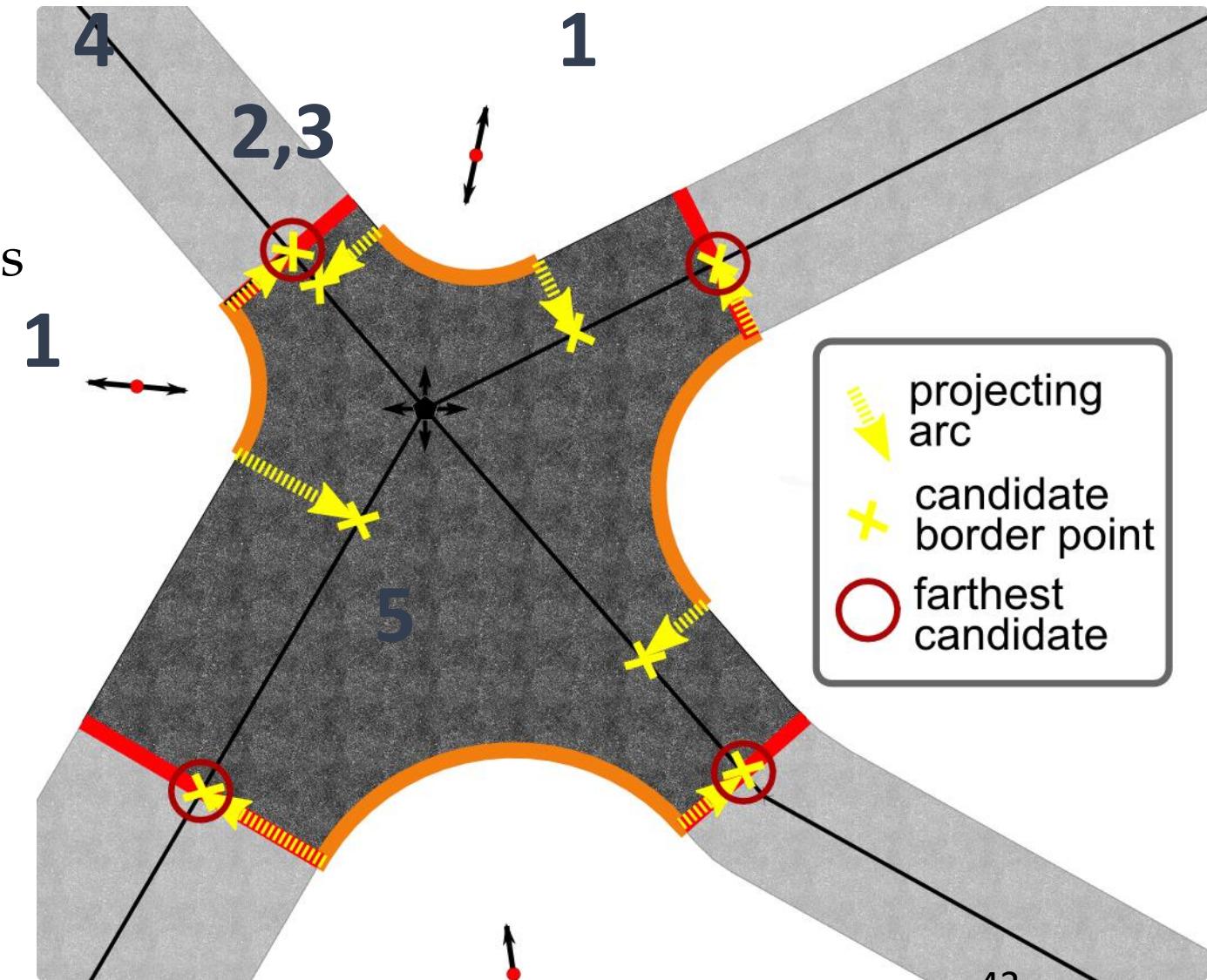


```

edge id=15; next_l=16
end_node=3 ...
edge id=16; next_l=17
start_node=4 ...
    
```

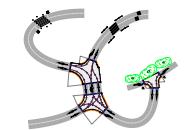
$r=3.6$
 $r=6.4$

- Find intersection limit :
 - Project circle centers
 - Farthest per axis



StreetGen : Road surface

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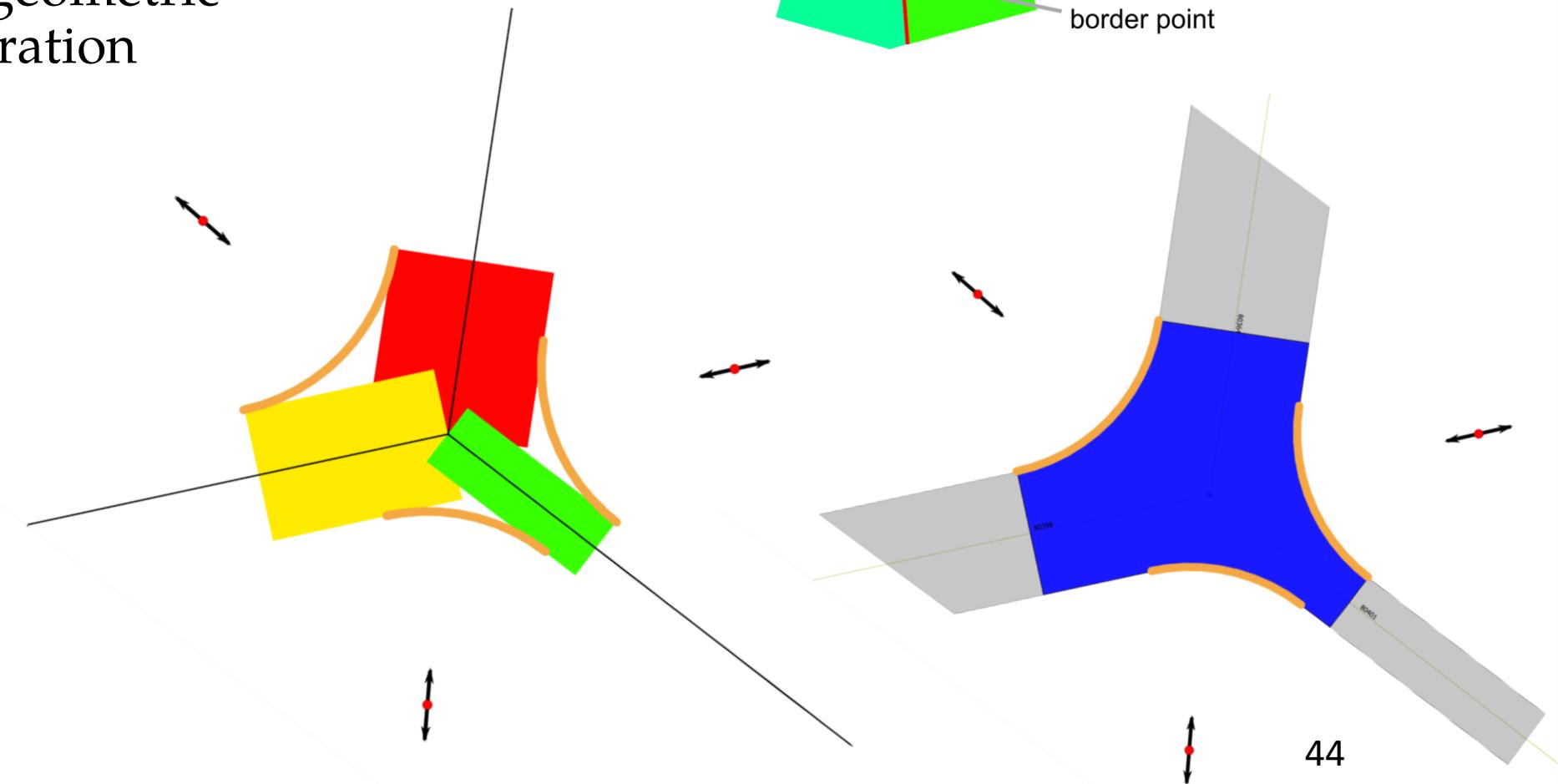
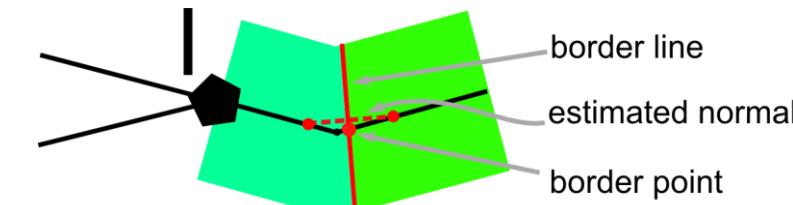
edge id=15; next_l=16
end_node=3 ...

edge id=16; next_l=17
start_node=4 ...

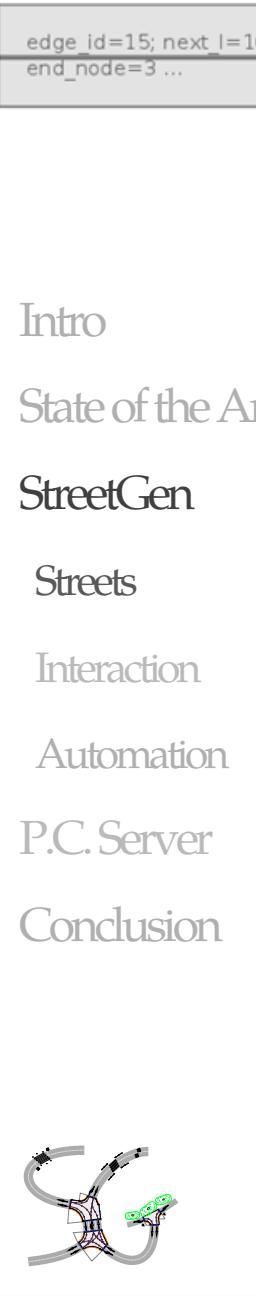
r=3.6 +

r=6.4 +

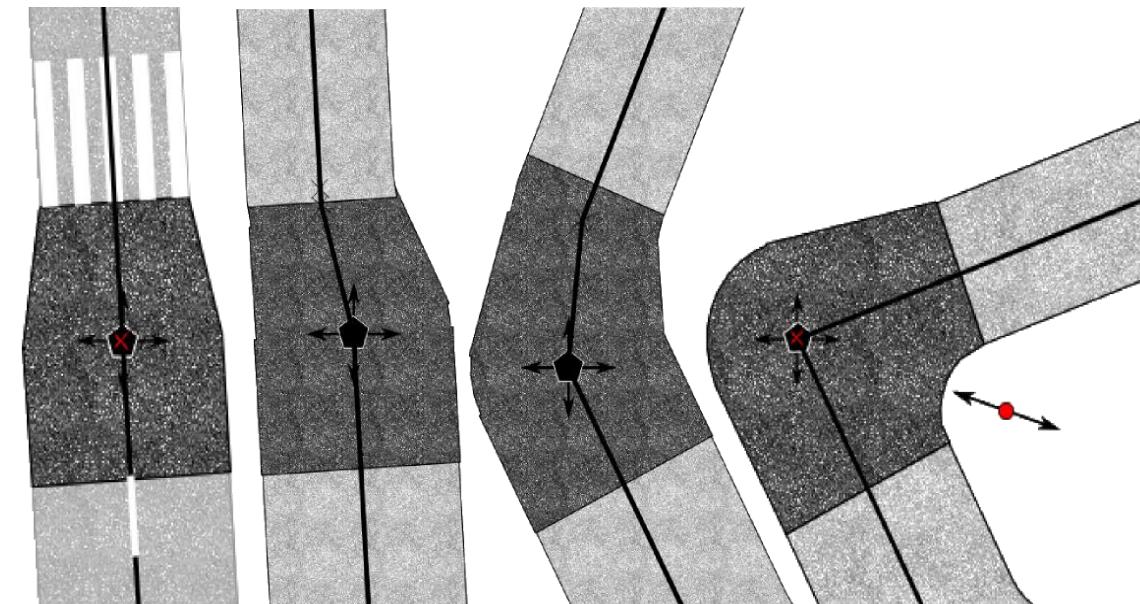
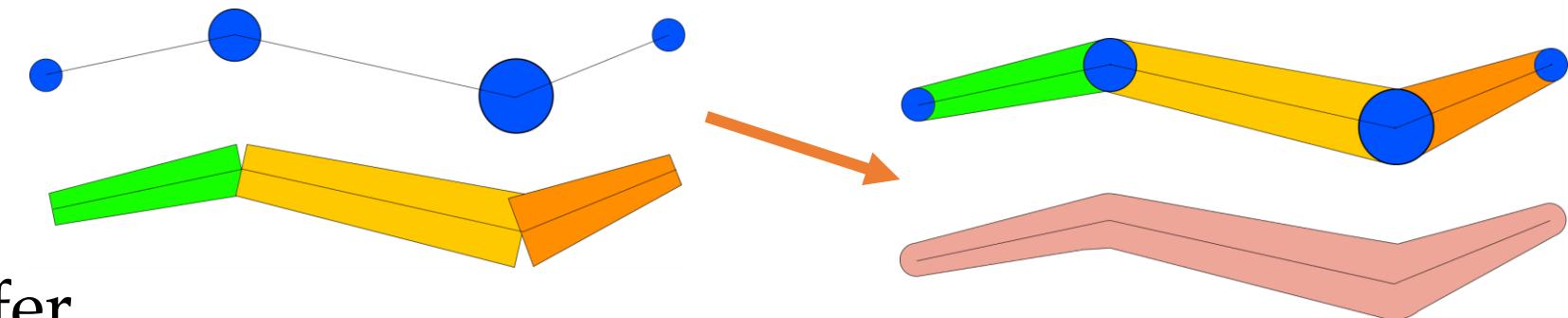
- Intersection surface :
 - By geometric operation



StreetGen : Road surface



- Special intersection:
- Variable buffer



StreetGen : Road surface

edge id=15; next_l=16
end_node=3 ...

- results

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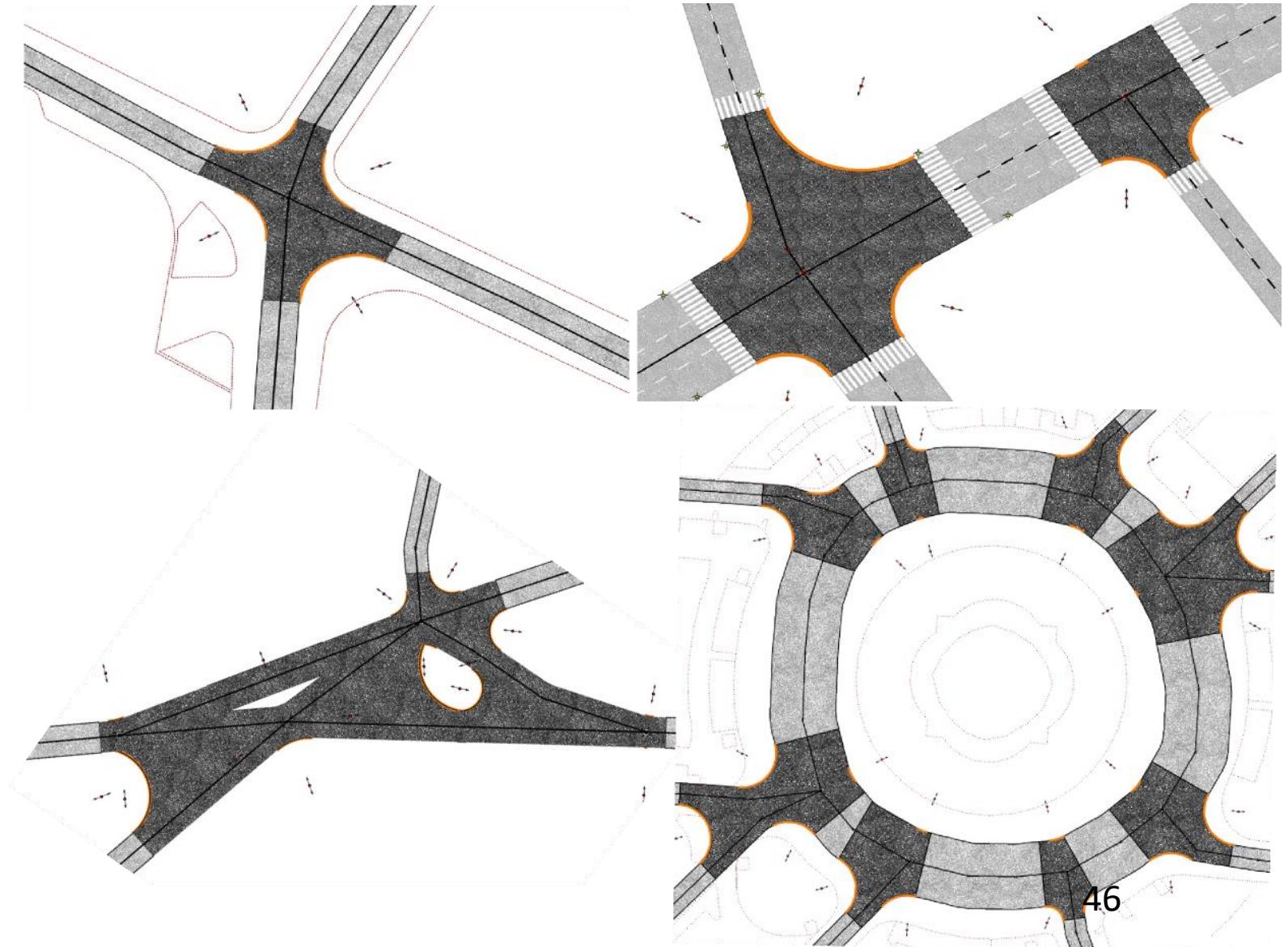
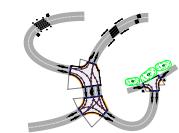
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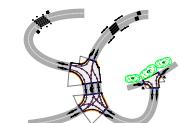
P.C. Server

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StreetGen : Road surface

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- Results whole P

Todo : merge this slide with previous by
putting small zoom balloons



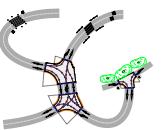
edge id=15; next_l=16
end_node=3 ...

edge id=16; next_l=17
start_node=4 ...

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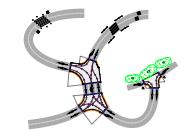
StreetGen : generate streets

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Kinematic hypothesis
Road surface
Traffic support
Street objects

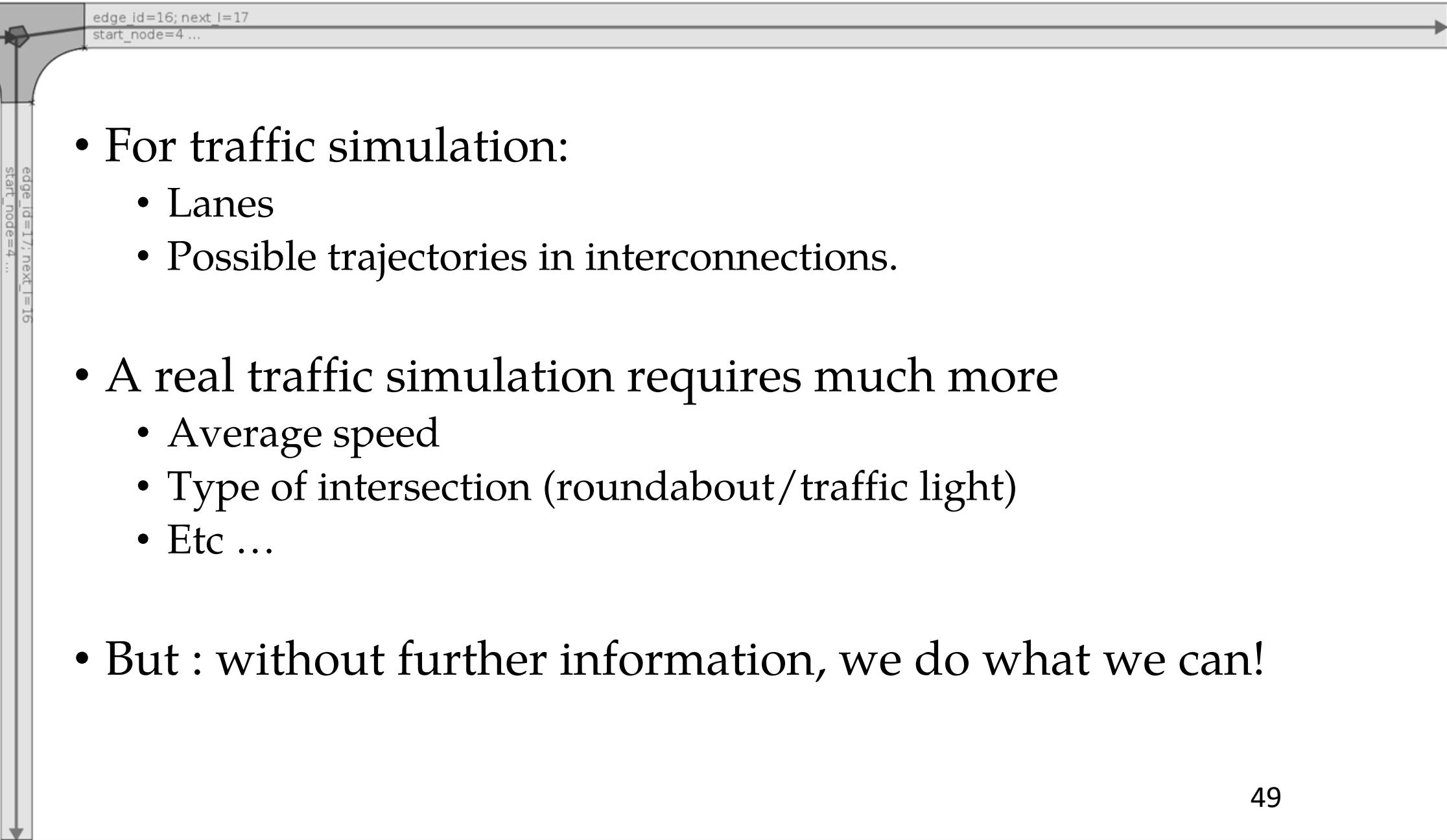


StreetGen : Traffic Support

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- For traffic simulation:
 - Lanes
 - Possible trajectories in interconnections.
- A real traffic simulation requires much more
 - Average speed
 - Type of intersection (roundabout/traffic light)
 - Etc ...
- But : without further information, we do what we can!



StreetGen : Traffic Support

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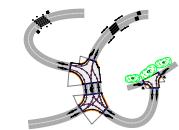
Streets

Interaction

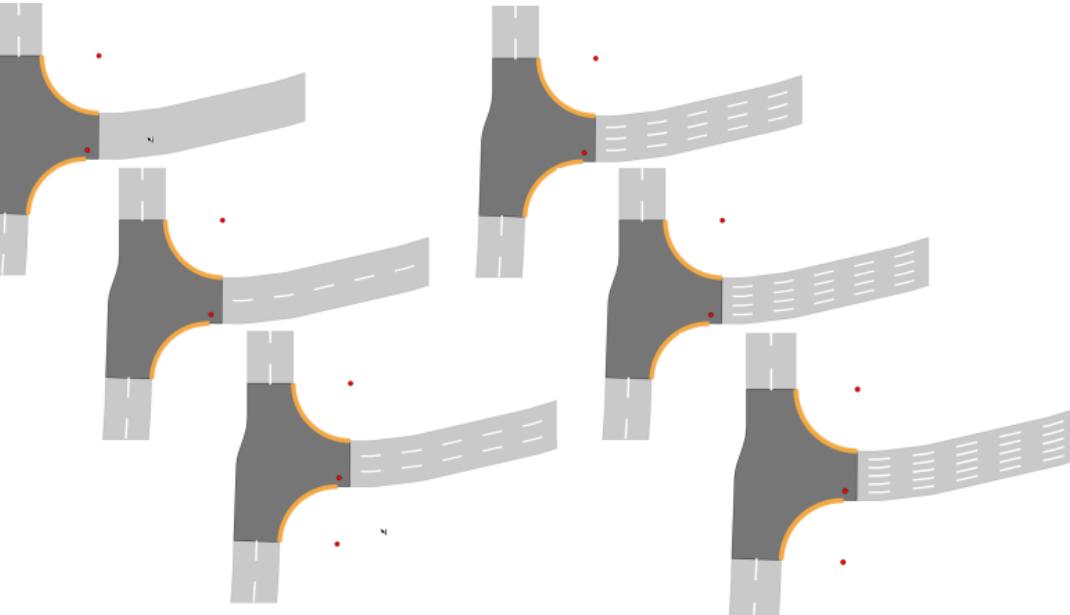
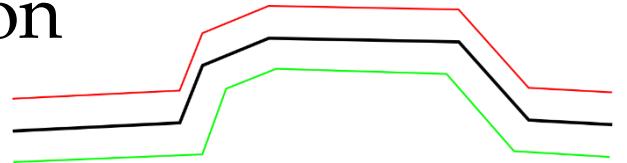
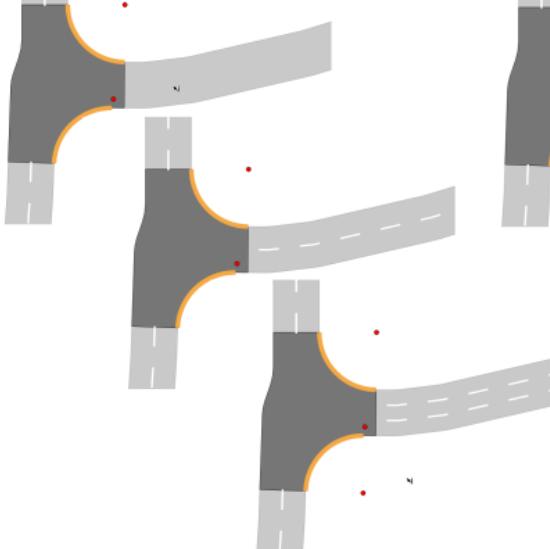
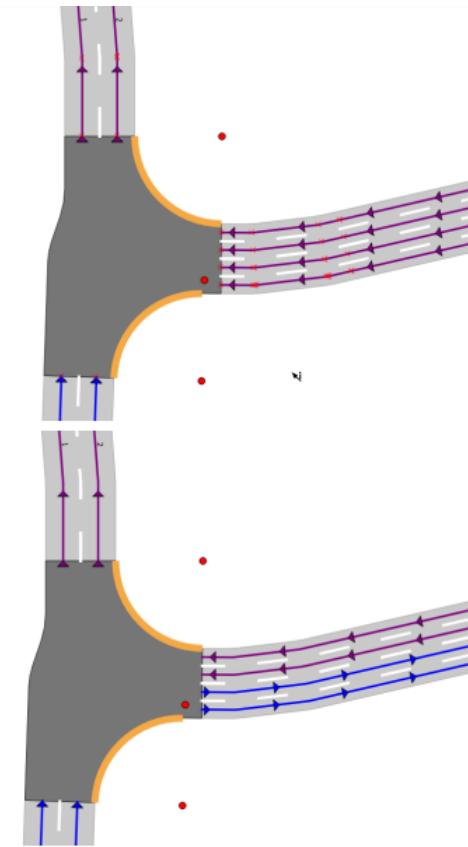
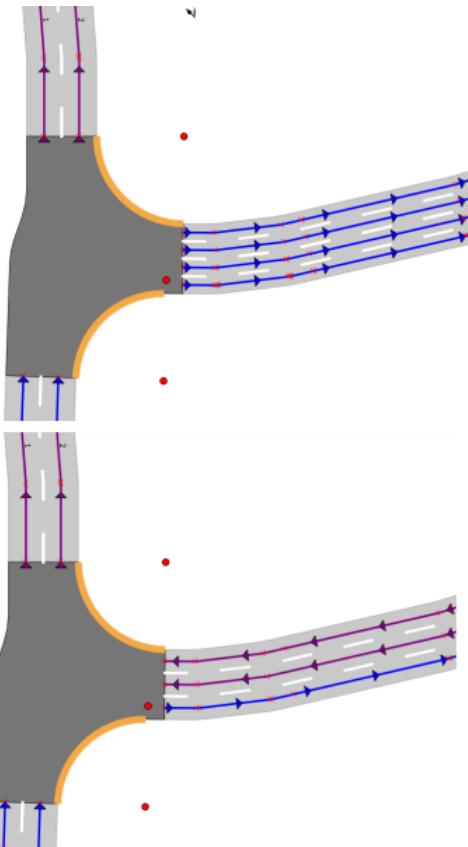
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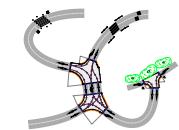


- Lane based on road axis : but not translation

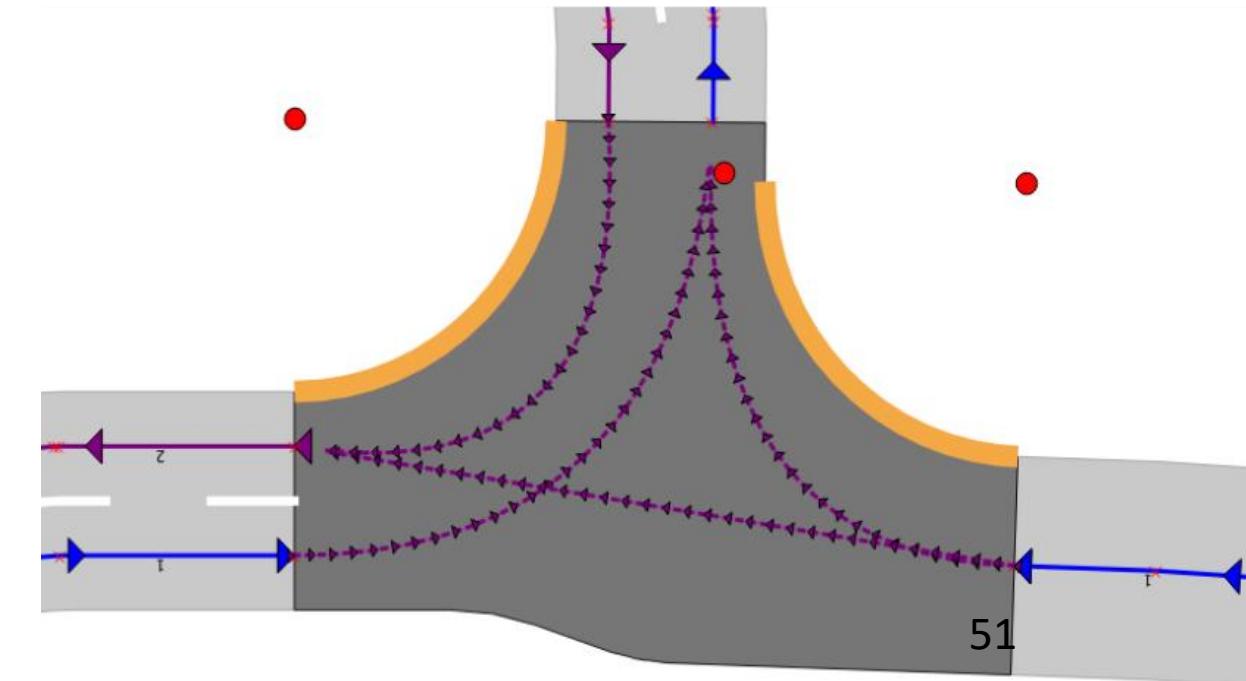
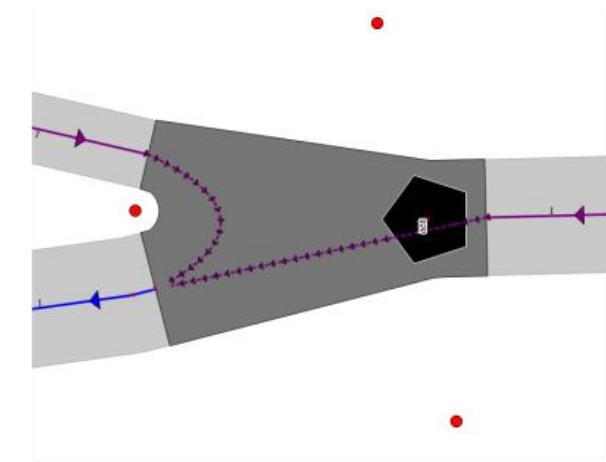
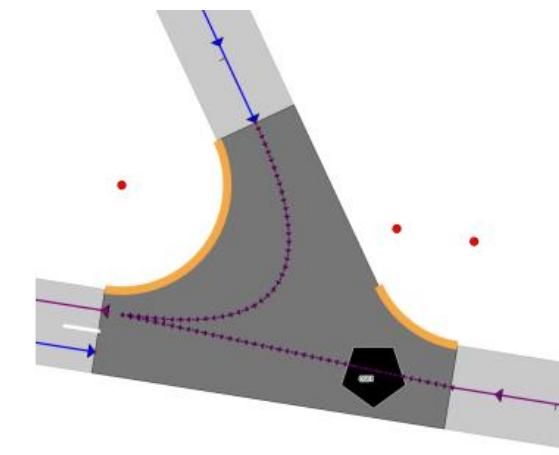


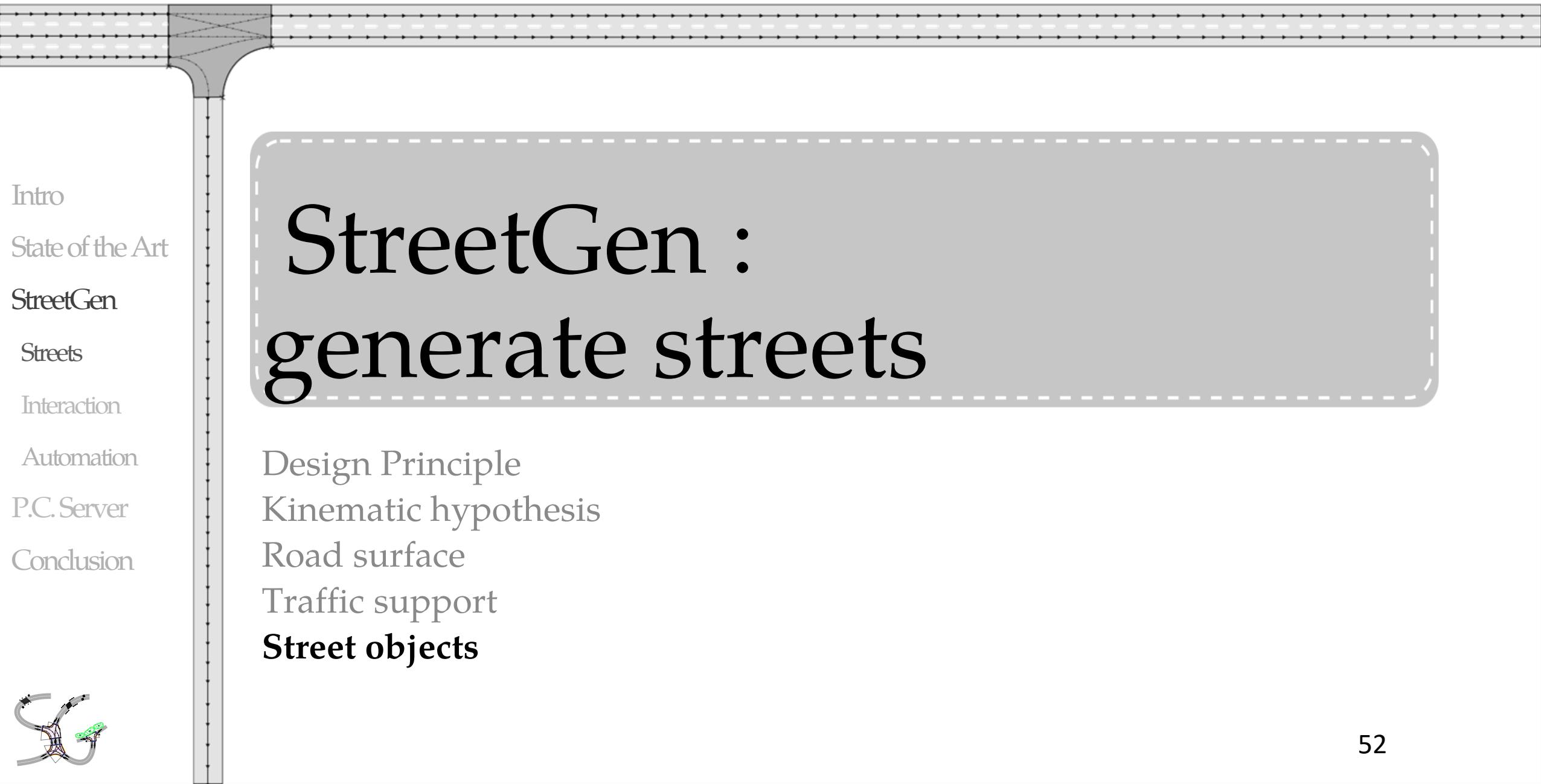
StreetGen : Traffic Support

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- Intersection trajectory : Bezier curves:
 - Not accurate (cinematically), but easy to create and edit
 - Involves center of intersection in special cases



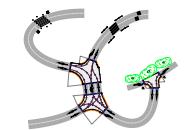


StreetGen : generate streets

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Road surface
Traffic support
Street objects

StreetGen : street objects

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- Streets objects : incredibly varied
 - 13k references on ArchiExpo
 - Markings : 1k pages of norms
 - ...
 - Objects are in relation (hierarchical, spatial, semantic ...)
 - Not many common points between all kind of street objects
 - Street objects are often spatially organized relatively to the street axis

StreetGen : street objects

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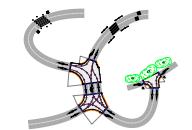
Streets

Interaction

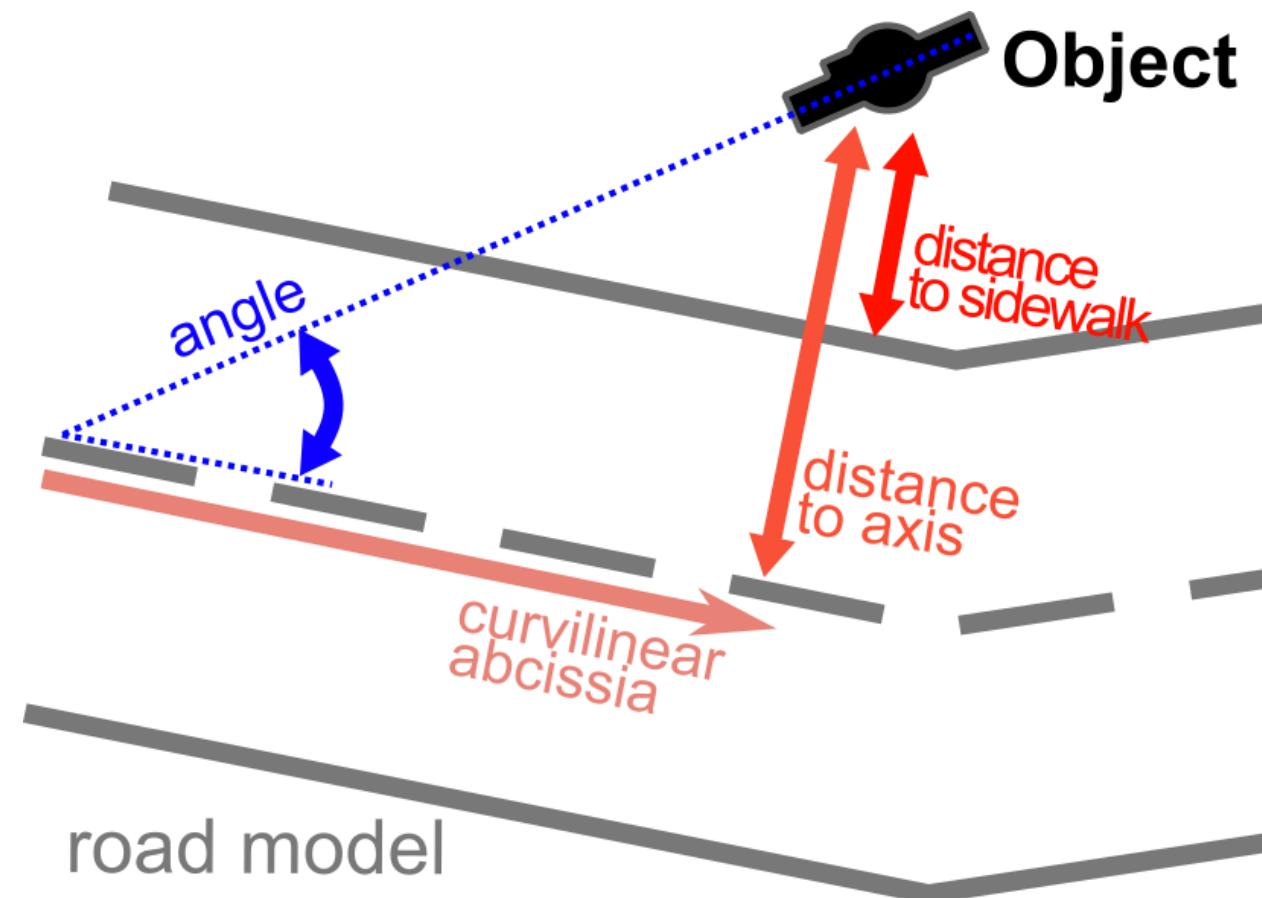
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- So we use generic objects
 - Positioned/oriented relatively to street axis



StreetGen : street objects

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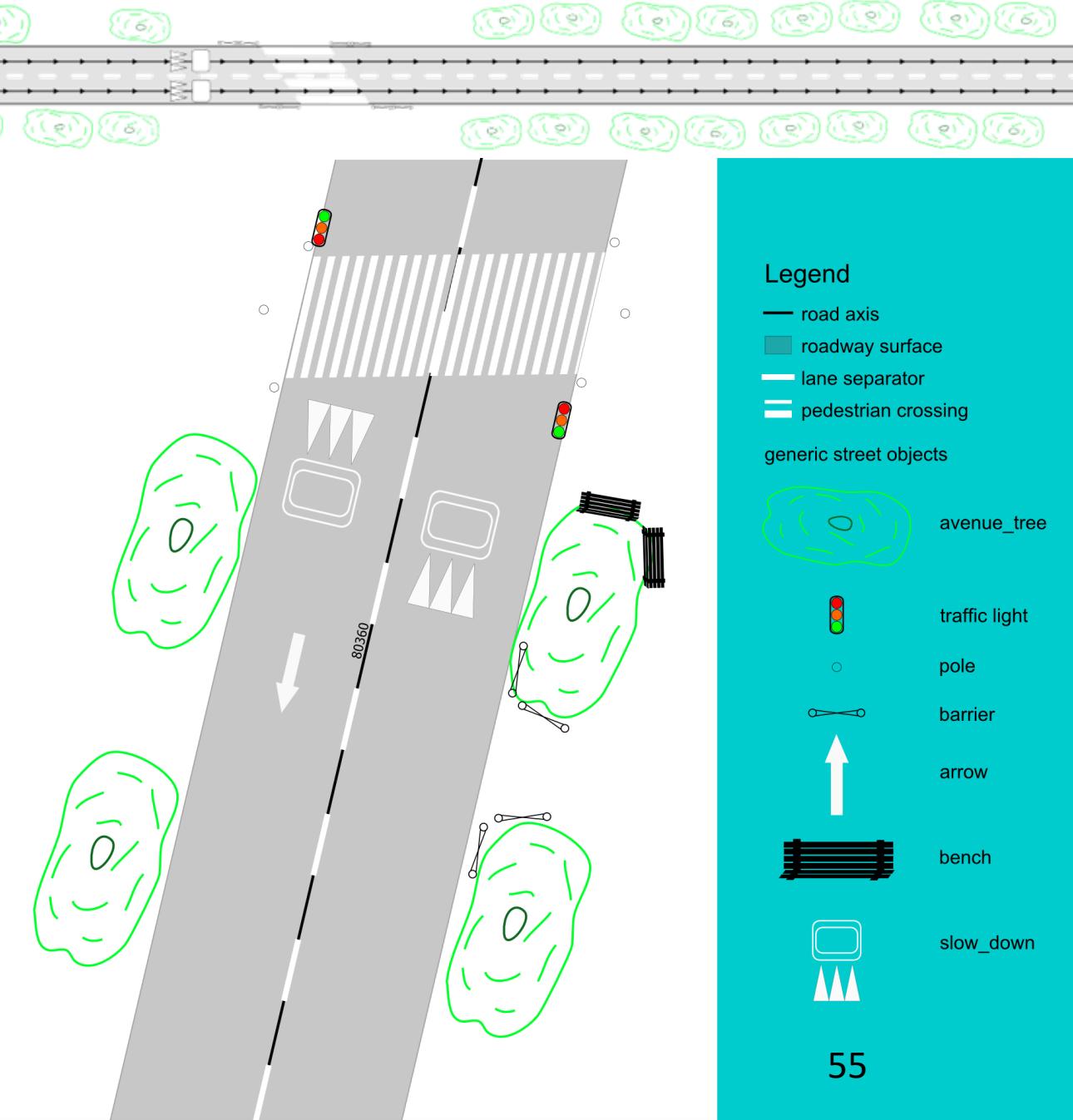
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Conclusion



- Objects are points with semantic
- DBMS can support any relation (hierarchy, semantic...)



StreetGen : street objects

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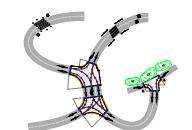
Streets

Interaction

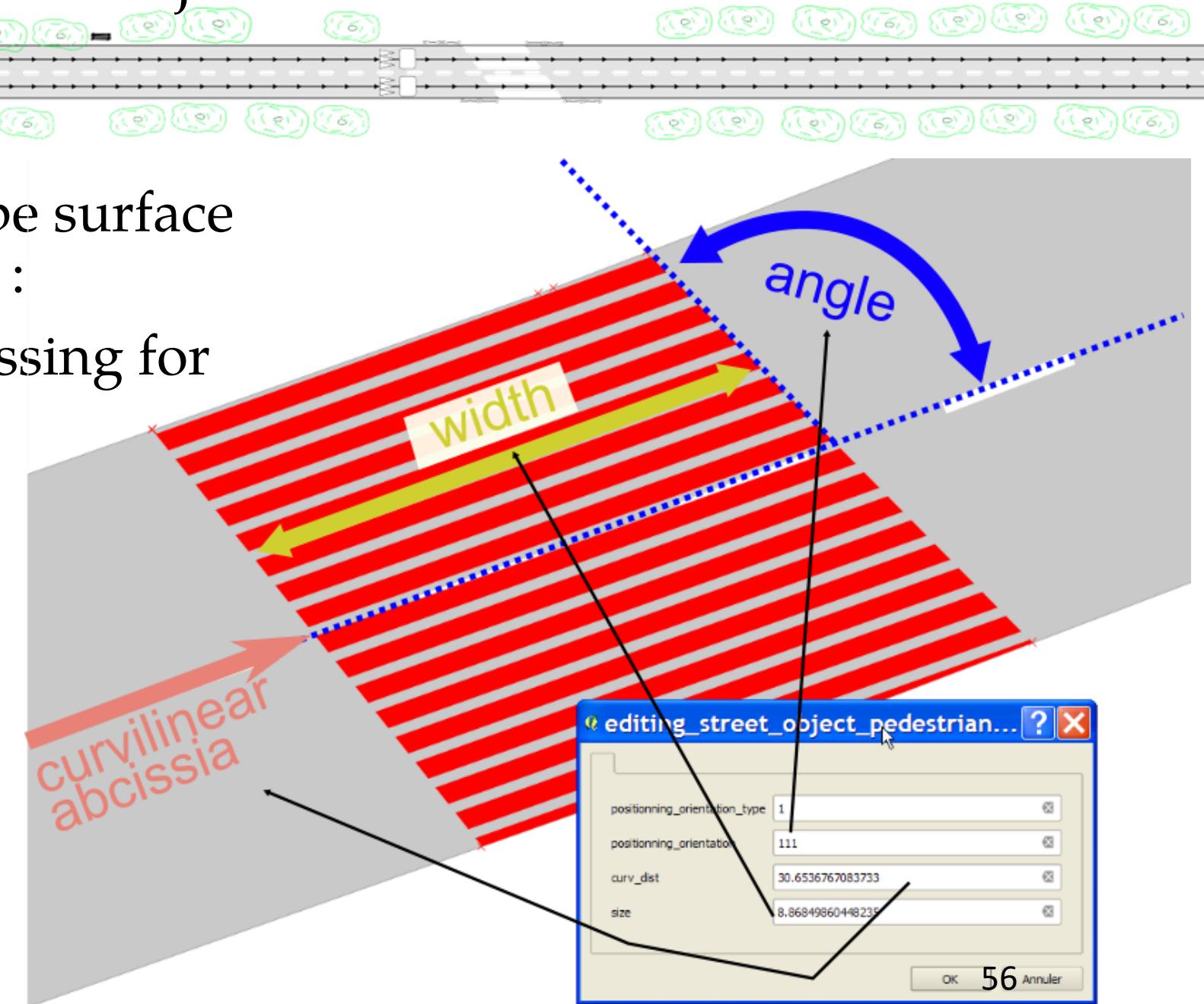
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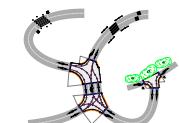


- Also can also be surface (or polylines?) :
- Pedestrian crossing for instance

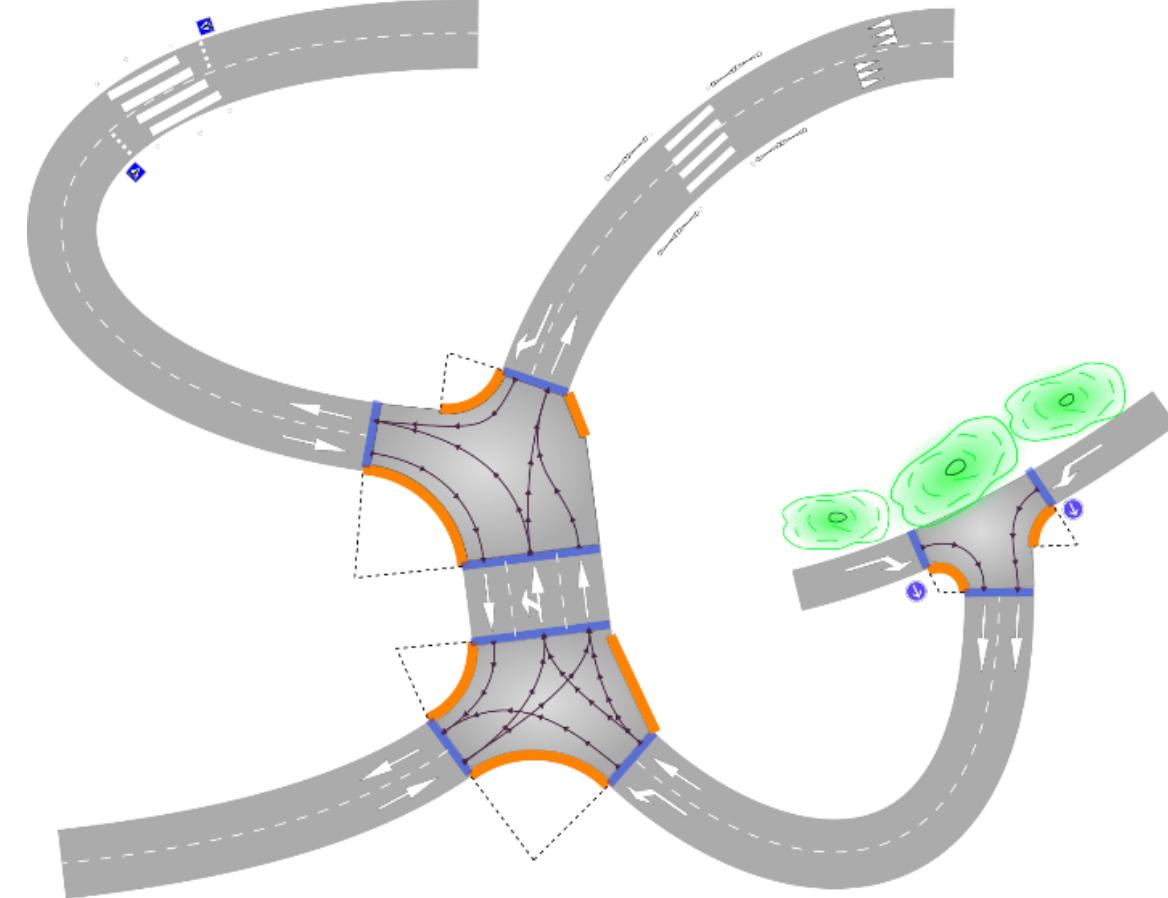
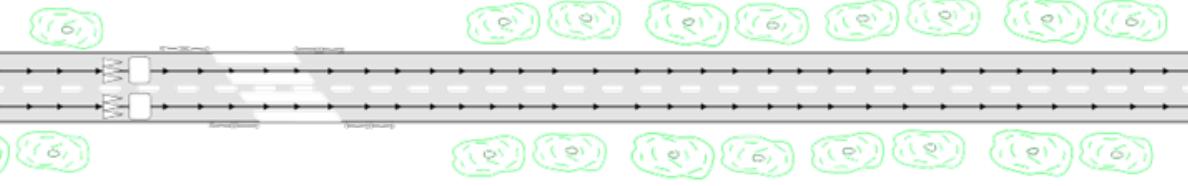


StreetGen : street objects

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- Whole Paris in 10 min.
- Tested for simulation (SimuVia)
- Tested for 3D visu (Thales NeoDBGS)
- Tested to model other cities (West Africa)
- Tested to model airport runway



StreetGen : street objects

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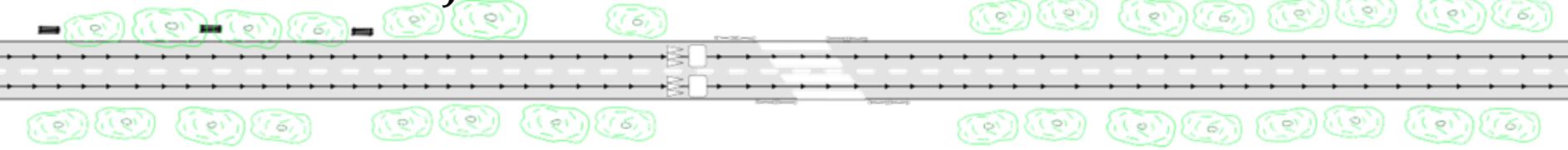
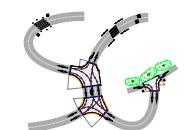
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Conclusion



- Of course, lot of limitations

- Street model:

- Not enough for some street
 - Radius seems to be historical rather than related to speed

- Technical

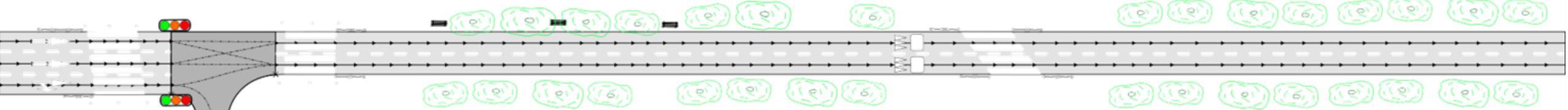
- Technical glitches/bugs
 - Precision issues

- Traffic

- All possible interconnection : too much

- Objects

- Lack linear objects

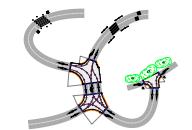


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StreetGen : editing streets (in-base)

In-base interaction Principle

- Edit road model
- Edit traffic
- Edit objects



StreetGen : street objects

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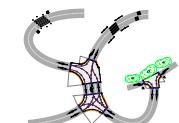
Streets

Interaction

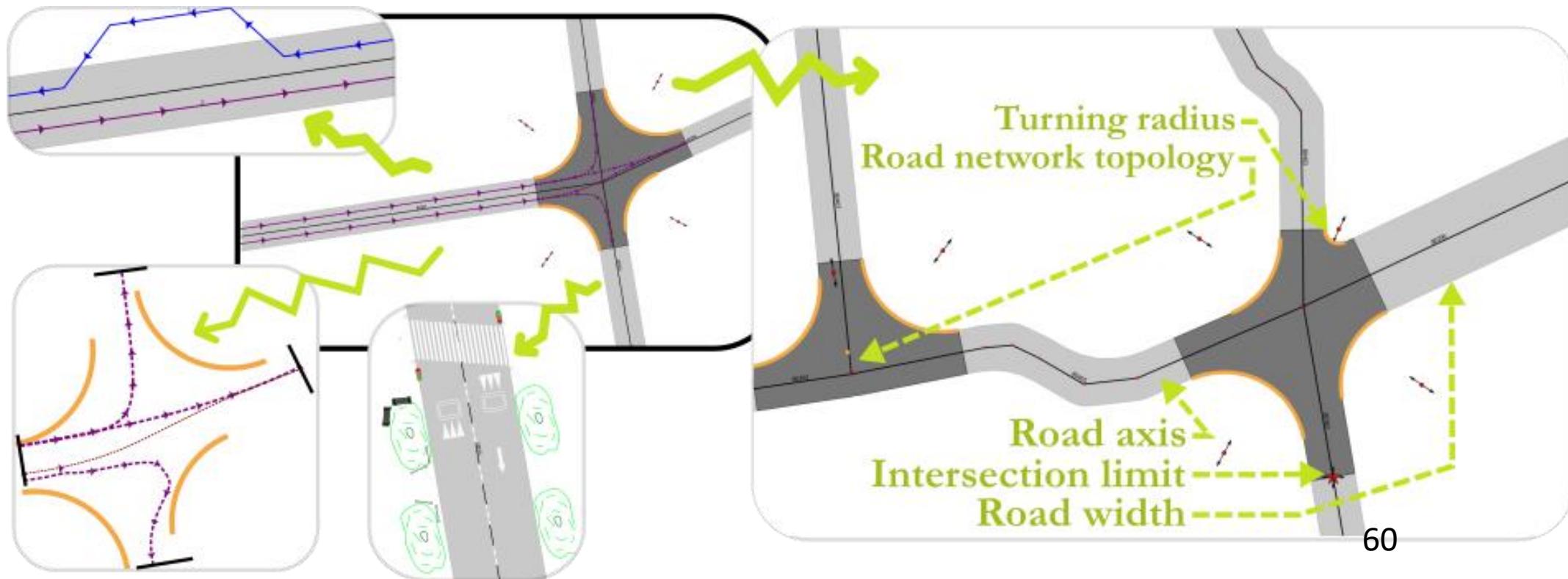
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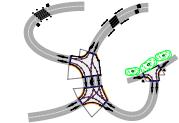


- How to edit street model easily (several concurrent users) ?

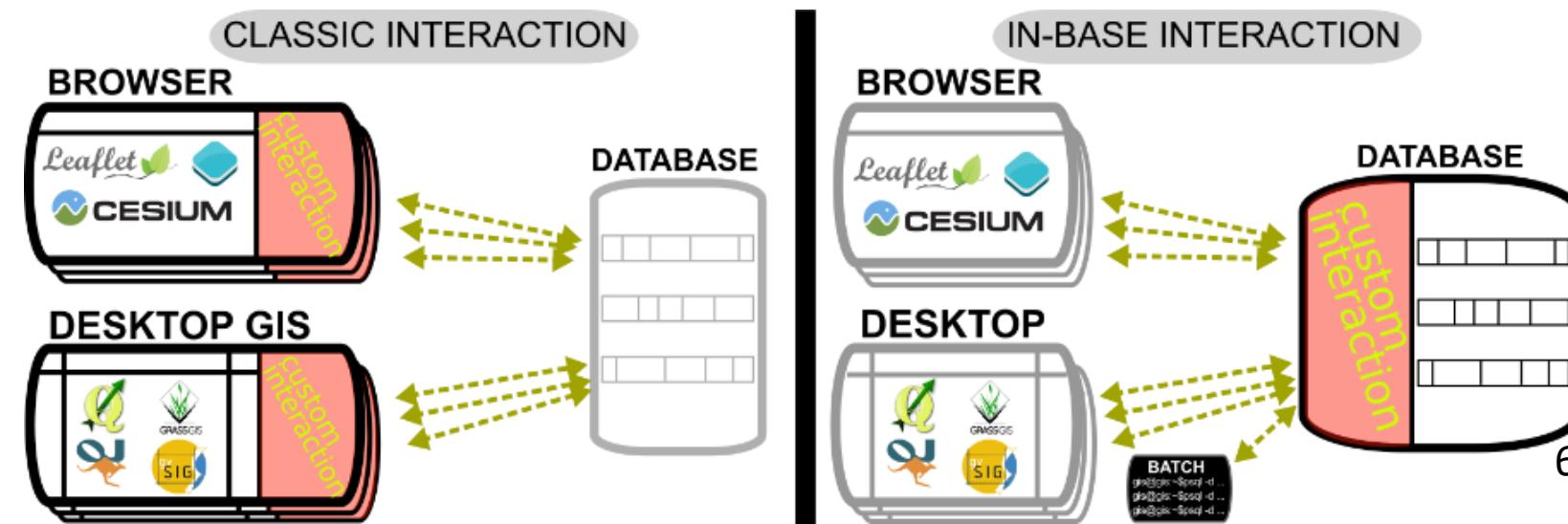


StreetGen : street objects

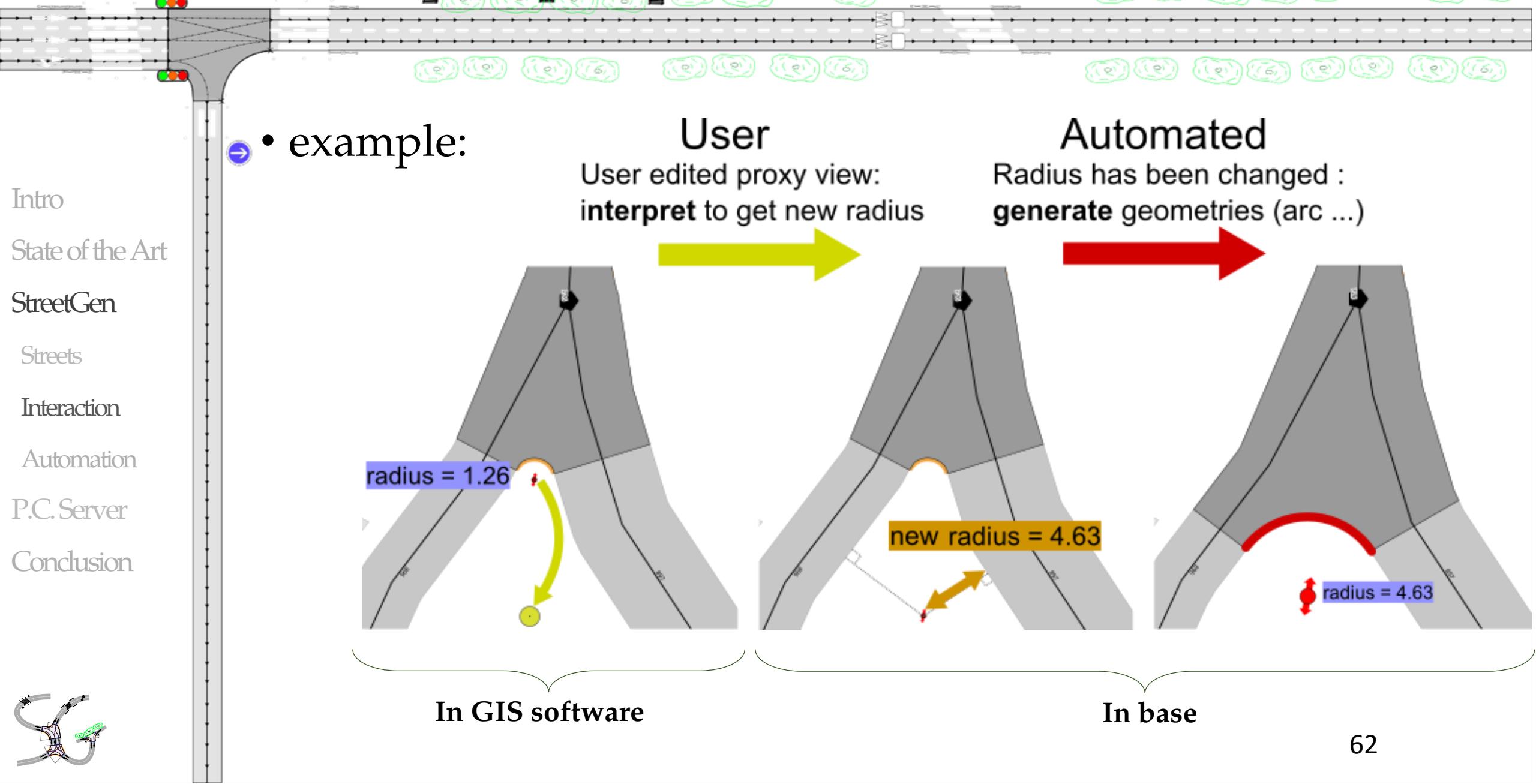
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- Fact : developing a Graphical User Interface (GUI) is hard, long and risky (maintenance)
- Many GUI for many tools (web/desktop/...)
 - Need to create plugins/interfaces/...
- Idea : use existing tools
 - GIS tools can already edit vector and attributes
 - specific interactions are in base



StreetGen : street objects



StreetGen : street objects

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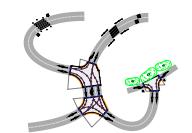
Streets

Interaction

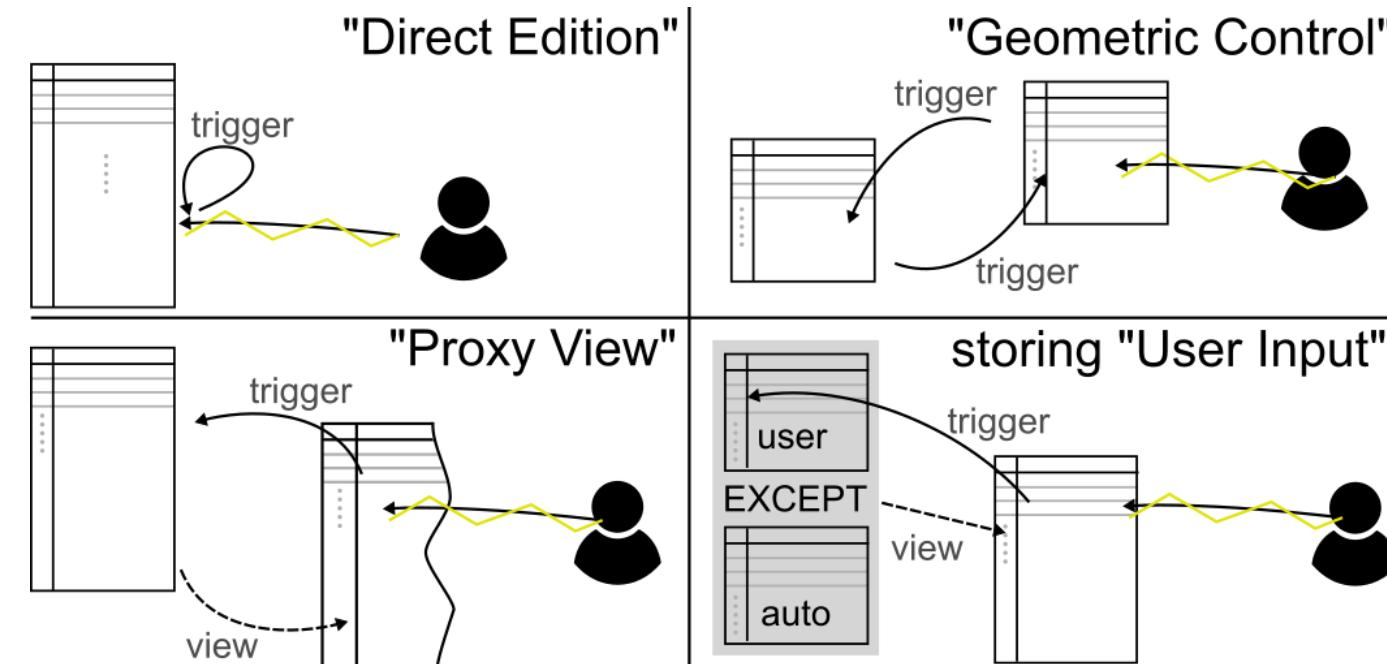
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Conclusion



- In-base interaction are generic and powerful
 - Design pattern to help use it for other applications



StreetGen : street objects

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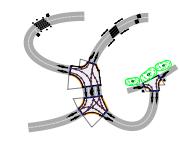
Streets

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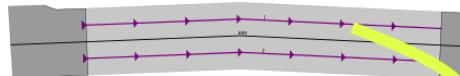
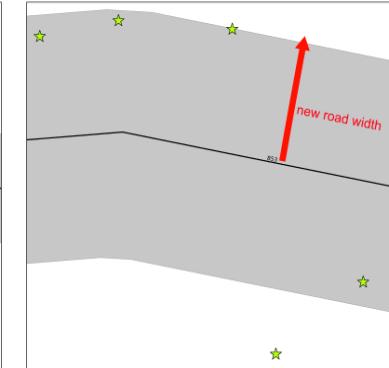
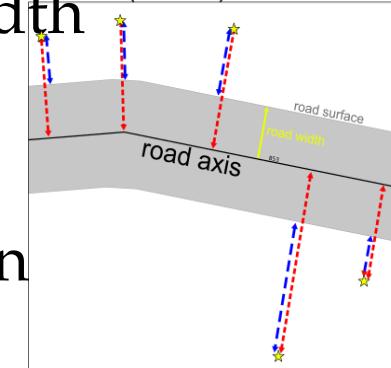
- All StreetGen street model can be edited concurrently

- Road axis / width
- Radius
- Lane
- Interconnection
- objects

① Assign curbstone points to road surfaces

② Compute new width (median)

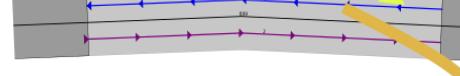
③ Update road width, regenerate



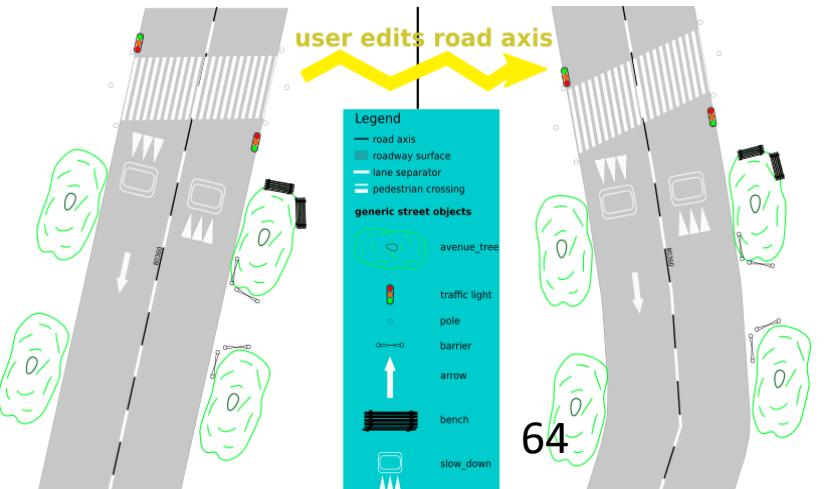
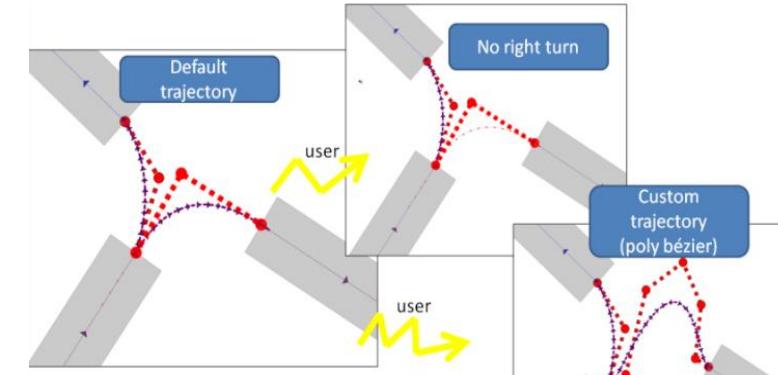
User overrides lane automatic direction :
UPSERT user input table. Geometry is still re-generated if necessary (default).

id	relates to	direction	geometry
12	302	True	NULL
...

User overrides lane geometry :
update user input table.
Geometry is now user fixed
+geom



User delete lane, which is interpreted as a reset:
Corresponding row in user input table is deleted.
Back to automatic generation



StreetGen : street objects

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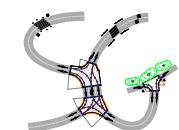
Streets

Interaction

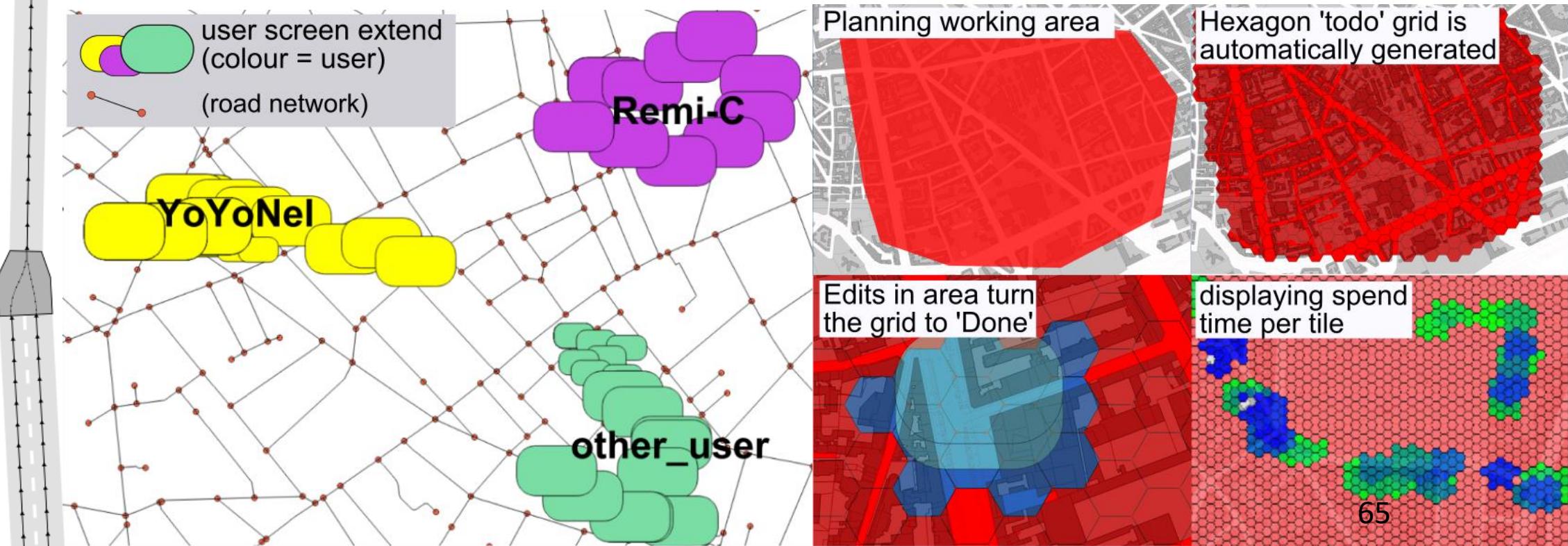
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Conclusion



- Multi-user editing can be facilitated
- “Interactive Map Tracking” QGIS plugin with Lionel Atty



StreetGen : street objects

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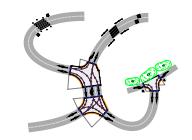
Streets

Interaction

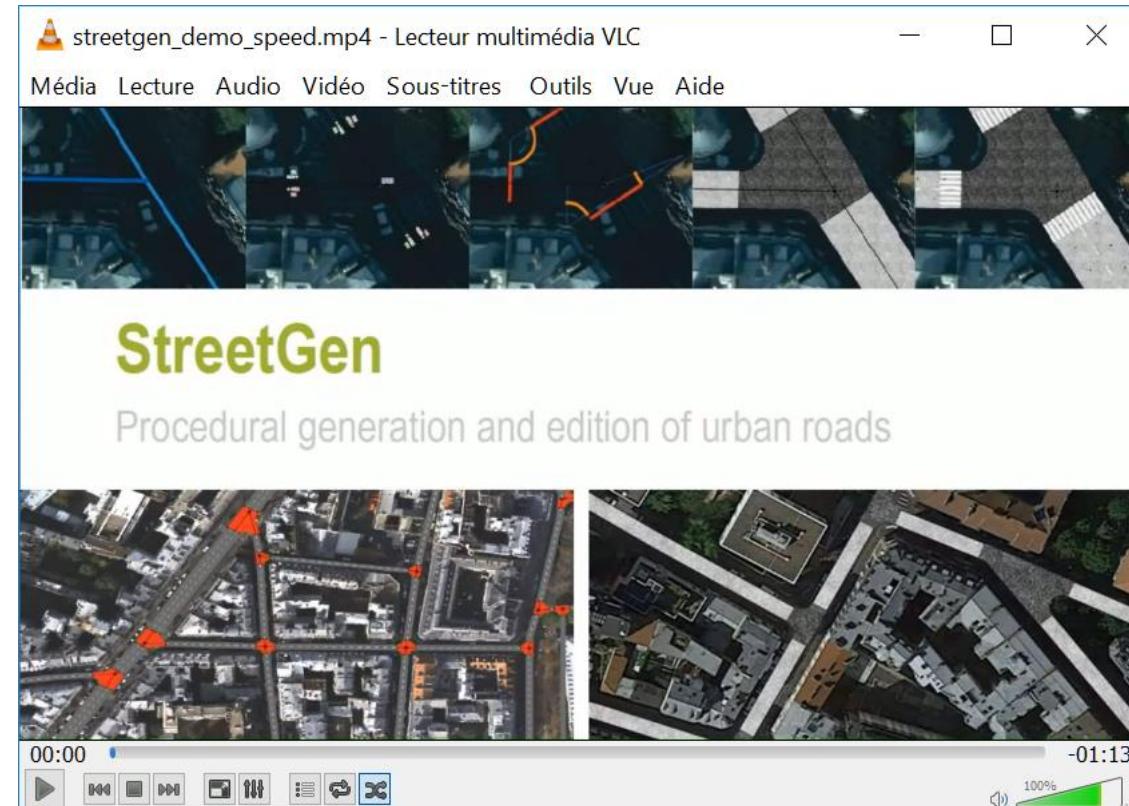
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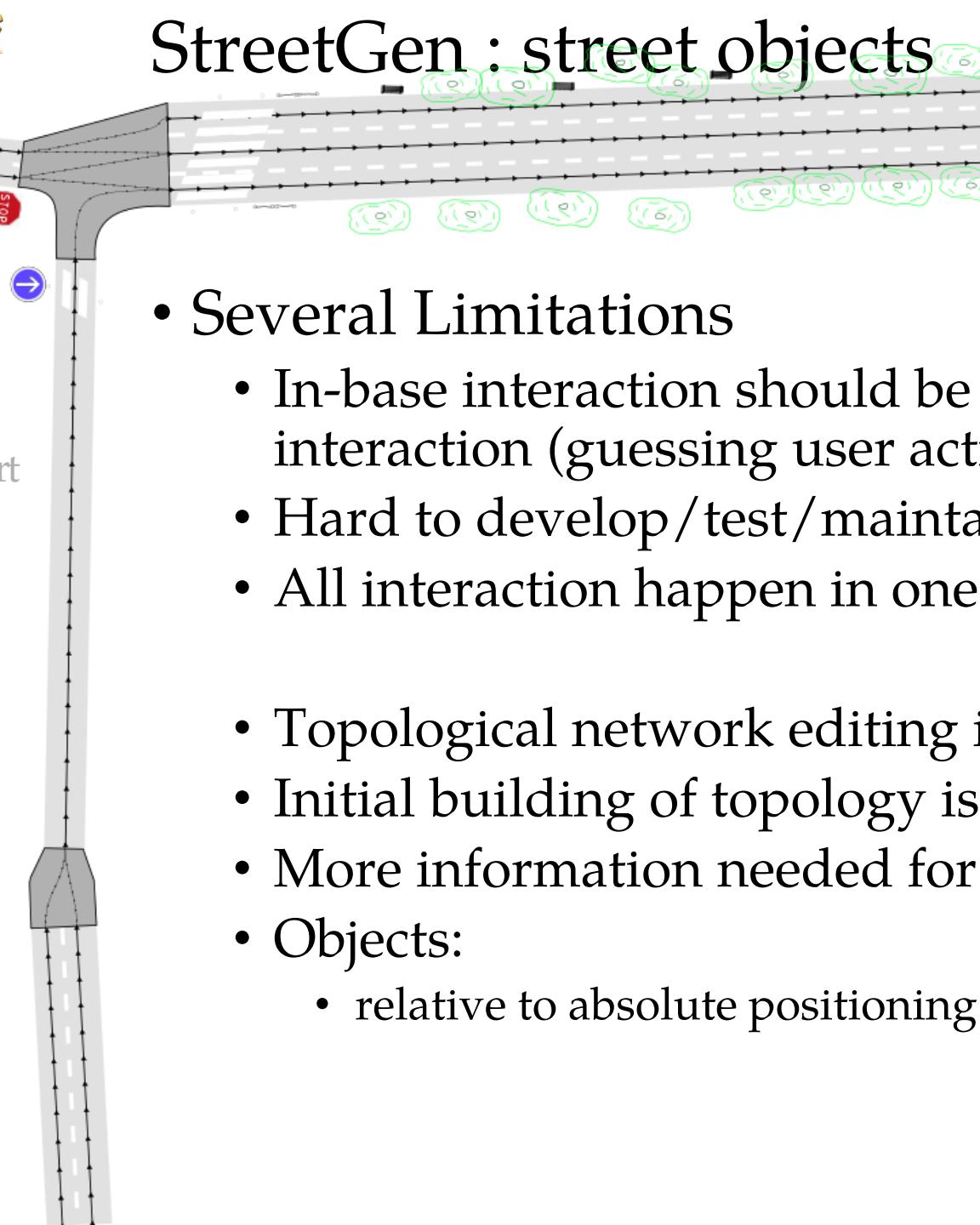
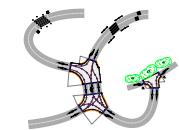
- Results:
 - Interaction are fast enough to be interactive



Video
<https://youtu.be/fQZoEfUcNHA>

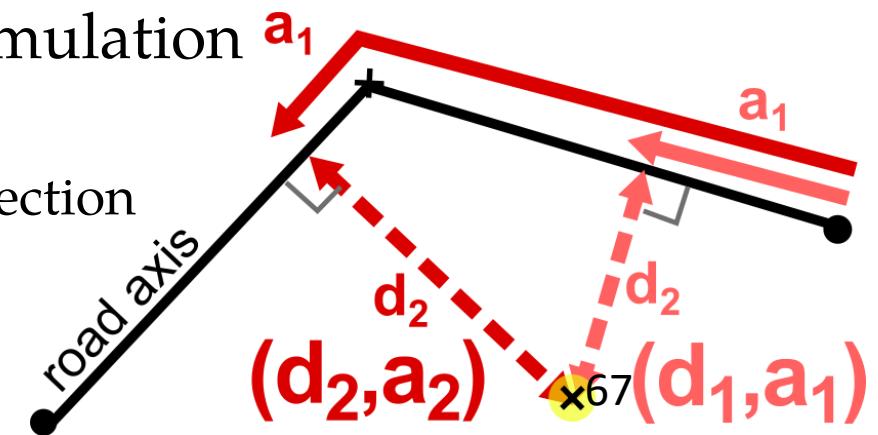
StreetGen : street objects

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- Several Limitations

- In-base interaction should be limited to straightforward interaction (guessing user action is easy)
- Hard to develop/test/maintain (no modern signal feature)
- All interaction happen in one transaction → should be short
- Topological network editing is limited (ill-posed problem)
- Initial building of topology is slow
- More information needed for traffic simulation
- Objects:
 - relative to absolute positioning is not a bijection



width= 8; lane= 3

width= 6; lane= 2

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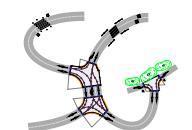
Conclusion

width= 4; lane= 1

Automating street modelling

Inverse procedural modelling concept

Fitting model to real streets



StreetGen : Inverse procedural modelling

width= 8; lane= 3

width= 6; lane= 2

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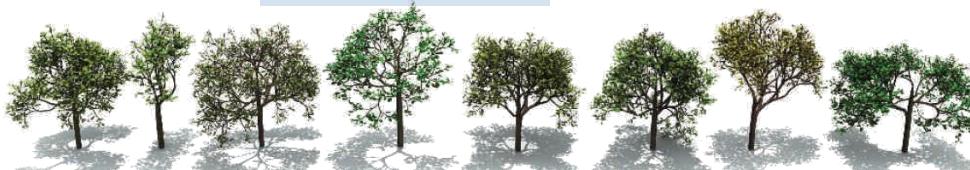
P.C. Server

Conclusion

Fit a generic
procedural model to a
specific situation

Specific situation?
→ We need data!

Talton2011



Todo : put another work

Simon2011

HOTEL SUIZO



Abstract

Chapter 2

Sensing data



Point Cloud Server

Chapter 2, 5
Appendix 1

Urban feature observations



Road axis + attributes



Chapter 3

Procedural Street Modelling

Chapter 4

Interactive
in base
edition

StreetGen

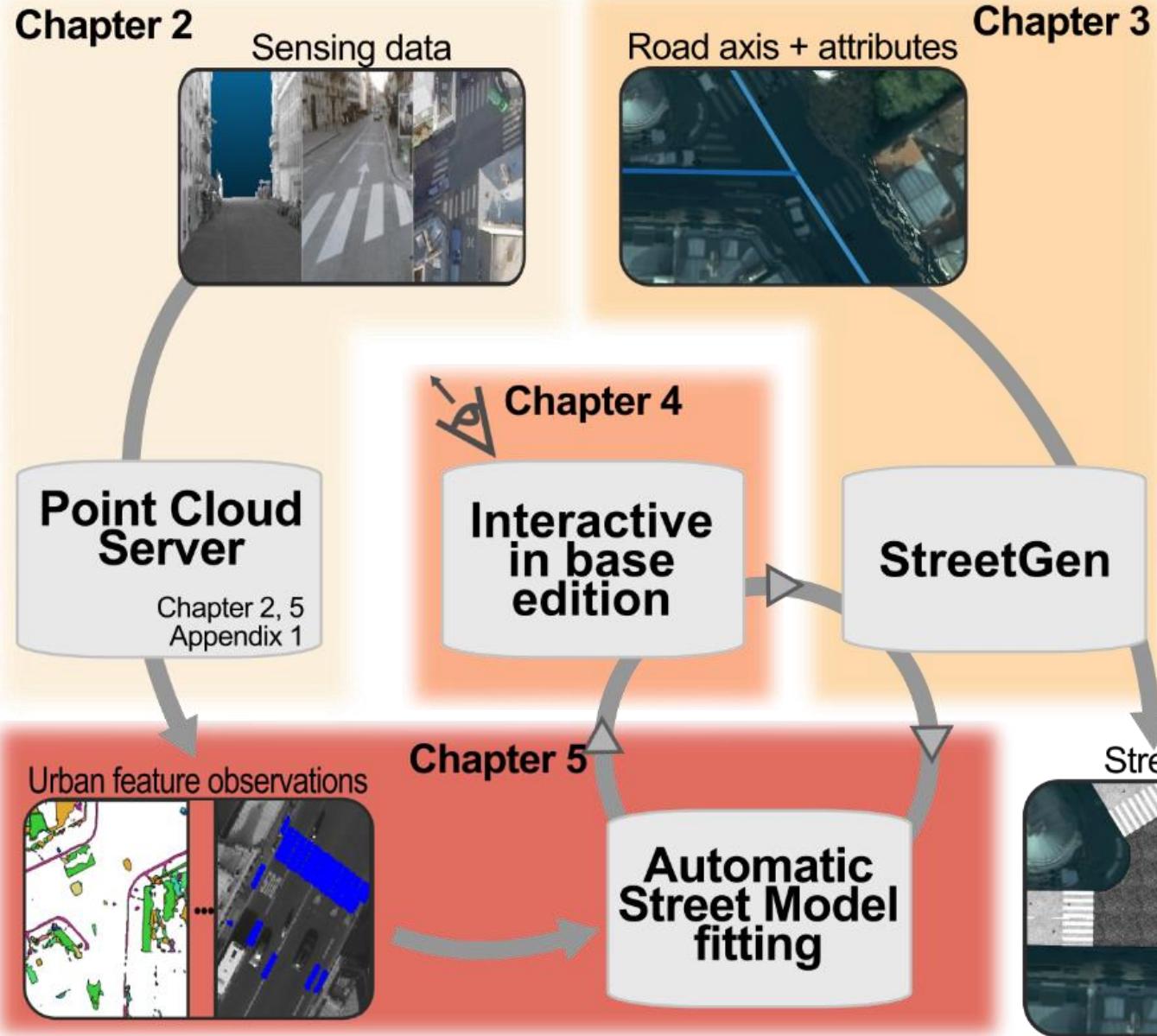
Chapter 5

Automatic
Street Model
fitting

Street Modelling



Abstract



Inverse Procedural Street Modelling

StreetGen : Inverse procedural modelling

width= 8; lane= 3

width= 6; lane= 2

- What type of data for streets?

- Precise
- Good coverage
- Frequent

- Aerial image?

- Good coverage
- Low 3D precision

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width= 4; lane= 1



StreetGen : Inverse procedural modelling

width= 8; lane= 3

width= 6; lane= 2

- IGN dedicated mobile mapping: Stereopolis
 - Cameras
 - Lidar

width= 4; lane= 1



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StreetGen : Inverse procedural modelling

width= 8; lane= 3

width= 6; lane= 2

Street view:

- Good coverage



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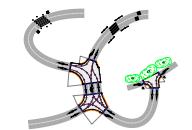
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width= 4; lane= 1



StreetGen : Inverse procedural modelling

width= 8; lane= 3

width= 6; lane= 2

Lidar: 3D point clouds

- precise 3D



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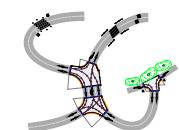
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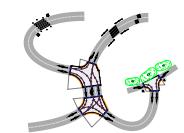


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Inverse procedural modelling concept

Fitting model to real streets



Inverse Procedural modelling: method

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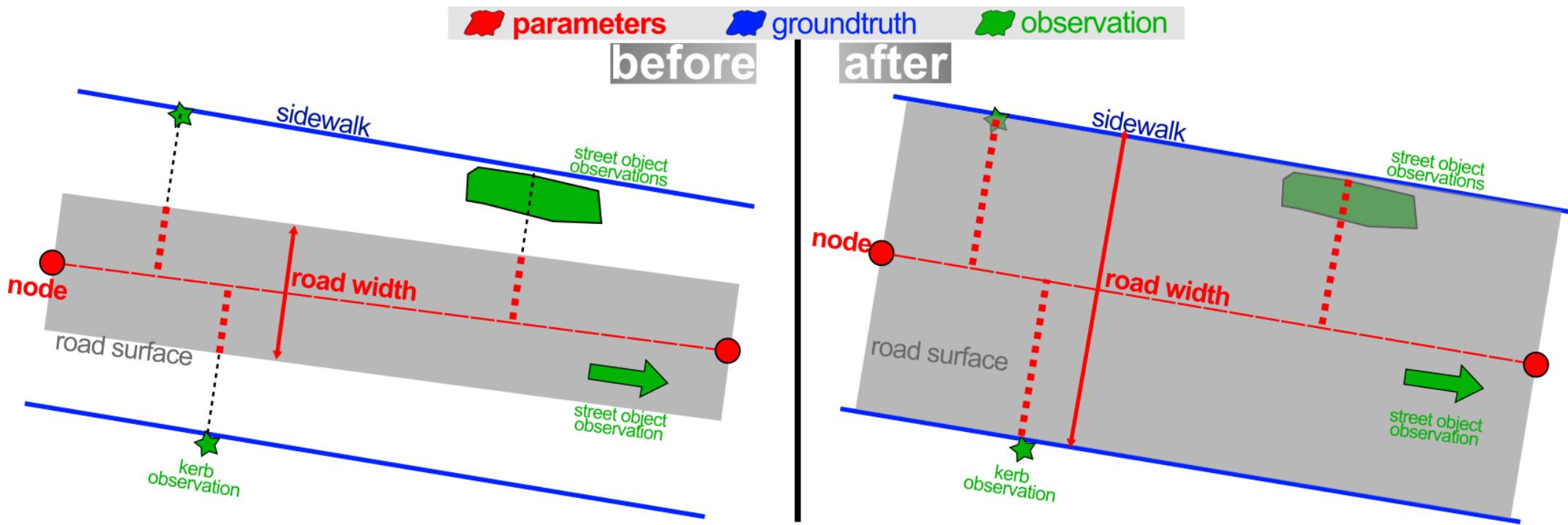
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- Initial road model + observation → optimisation → fit road model



Inverse Procedural modelling: method

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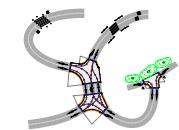
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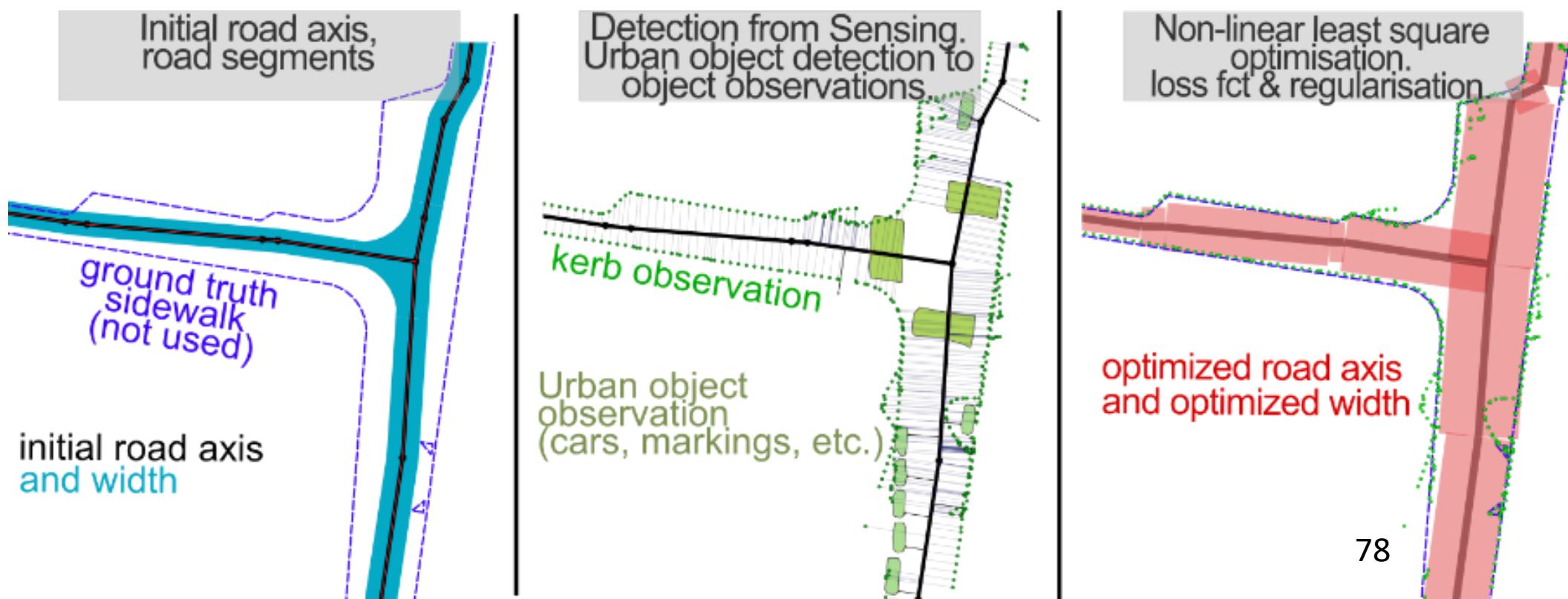
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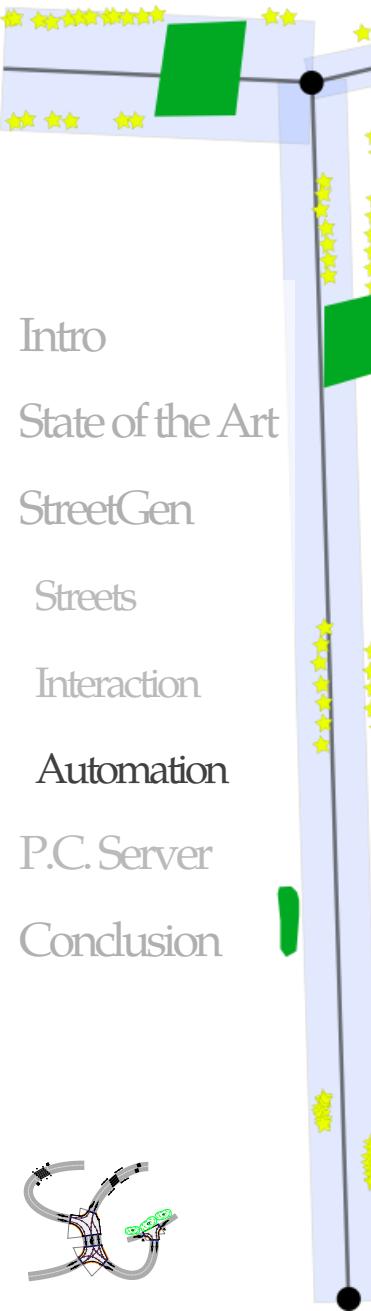
Conclusion



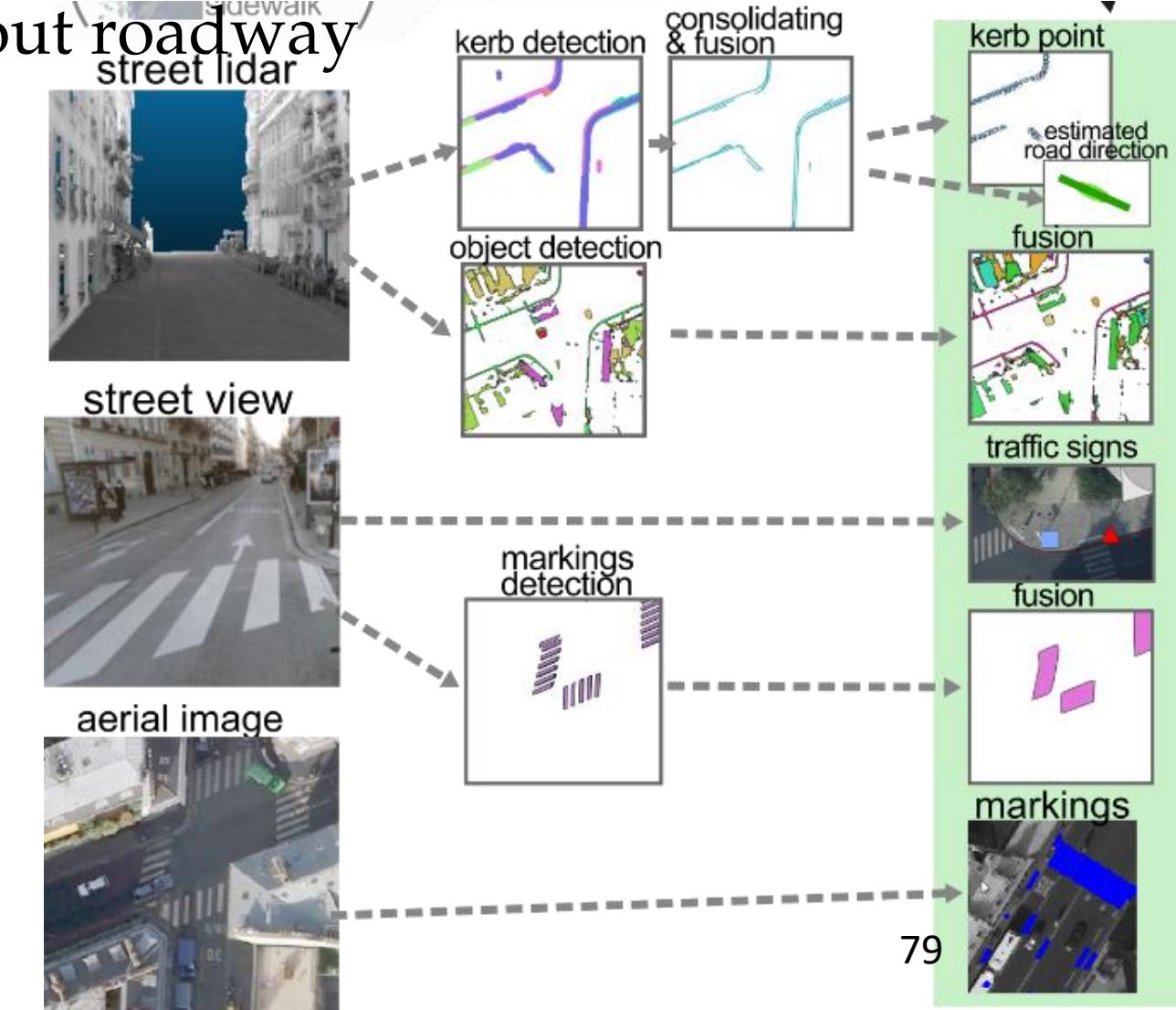
- Initial road model + observation → match observation to axis optimisation → fit road model



Inverse Procedural modelling: observations



- Observation = clues about roadway



Inverse Procedural modelling: observations

- Observation = clues about roadway

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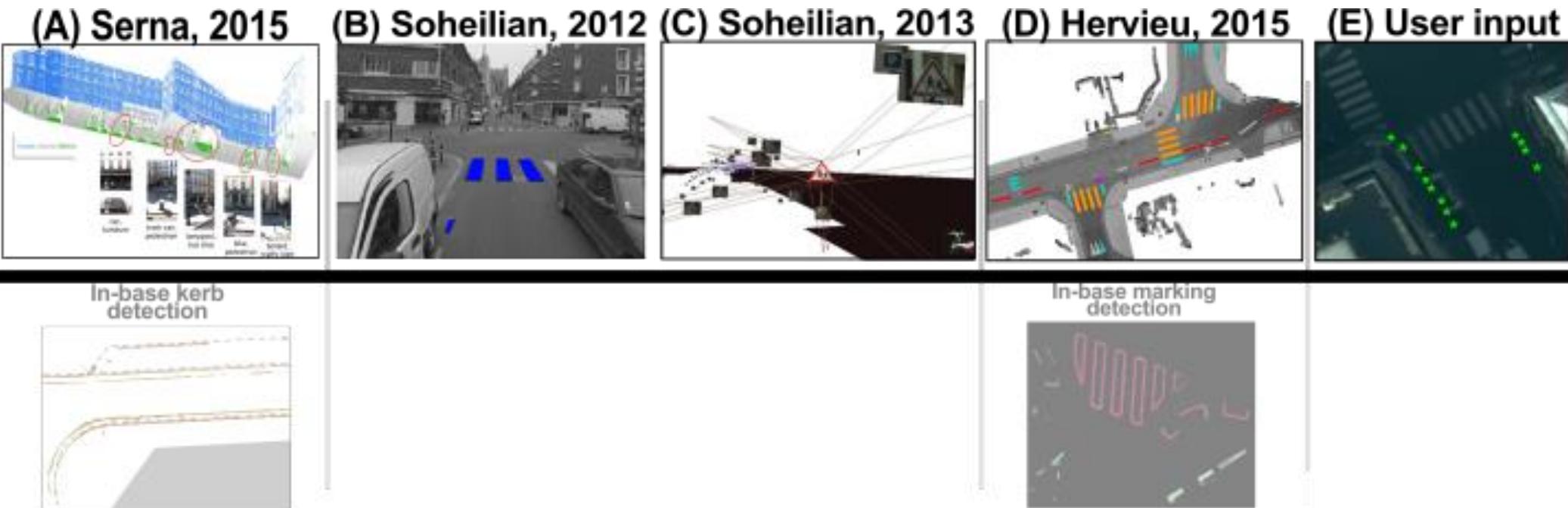
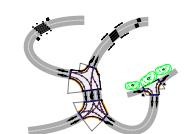
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Inverse Procedural modelling: forces

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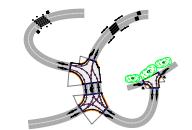
Streets

Interaction

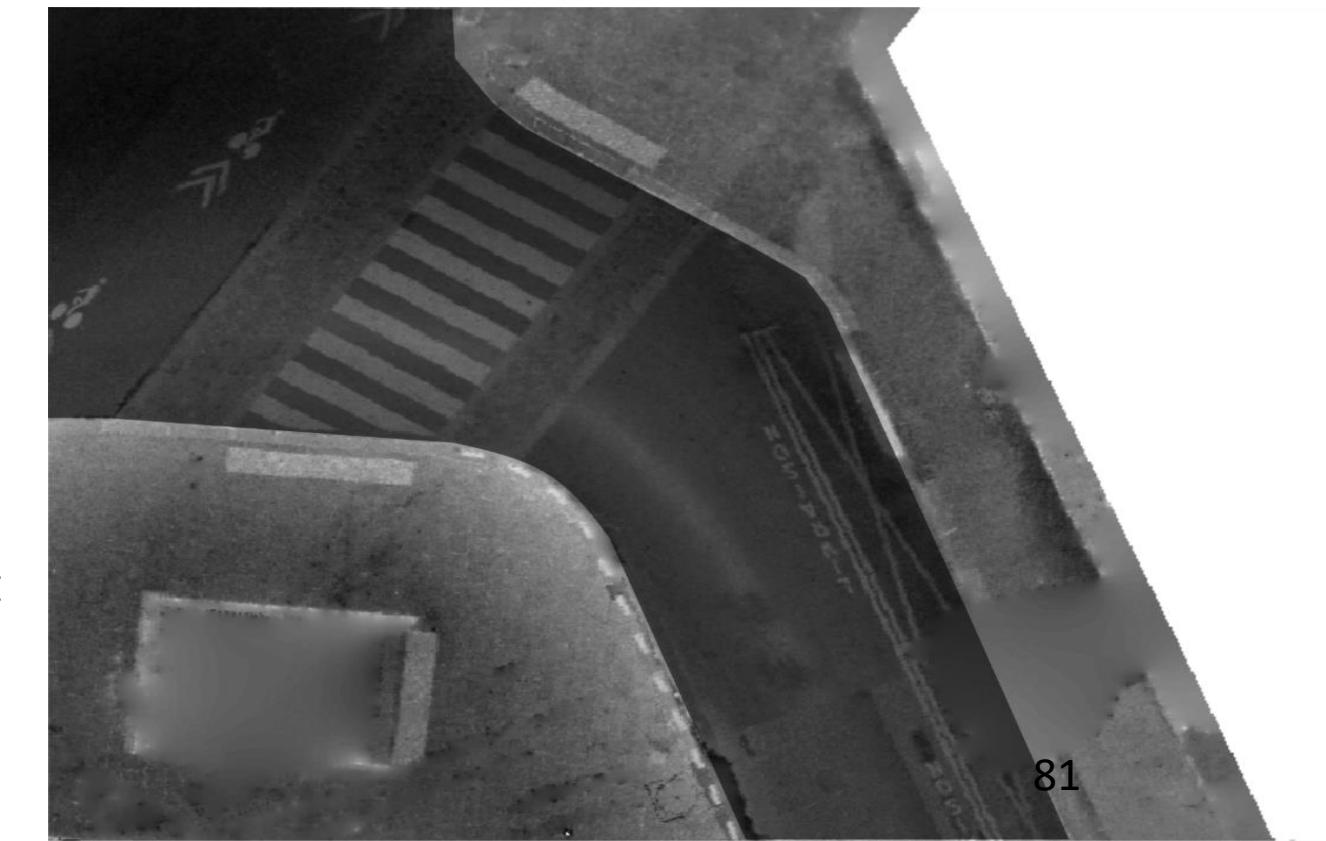
Automation

P.C. Server

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- Observations generate forces on road axis/width
- Each street object type has an expected position:
 - IN/OUT + BORDER_IN/BORDER_OUT (dist)
- Ex :
 - road markings : IN
 - Pedestrian crossing marking : BORDER_IN (0.2 m)
 - Traffic sign : OUT
 - No parking markings : BORDER_OUT (0.1m)



Inverse Procedural modelling: forces

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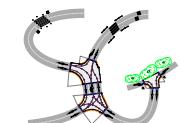
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Conclusion



- Each type of street object expected position is defined in a table

other static	COLLECTION	UNDEF	0	0	0
punctual object	POINT	UNDEF	0	0	0
other punctual	POINT	UNDEF	0	0	0
post	POINT	OUT	1	1	0
bollard	POINT	OUT	0.2	1	0.1
floor lamp	POINT	BORDER	0.2	1	0.2
traffic light	POINT	UNDEF	1	0	0
traffic sign	POINT	OUT	1	0	0
signboard	POINT	UNDEF	1	0	0
mailbox	POINT	OUT	0	1	0.2
trash can	POINT	OUT	0.5	1	0
meter	POINT	OUT	0	1	0.2
Velib terminal	POLYGON	UNDEF	0	0	0
linear	LINESTRING	UNDEF	0	0	0
other linear	LINESTRING	UNDEF	0	0	0
barrier	LINESTRING	BORDER_OUT	0.2	1	0.1
roasting	LINESTRING	OUT	0.2	1	0.1
arid	LINESTRING	OUT	0.2	1	0.1

Inverse Procedural modelling: forces

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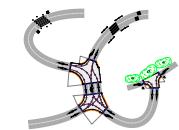
Streets

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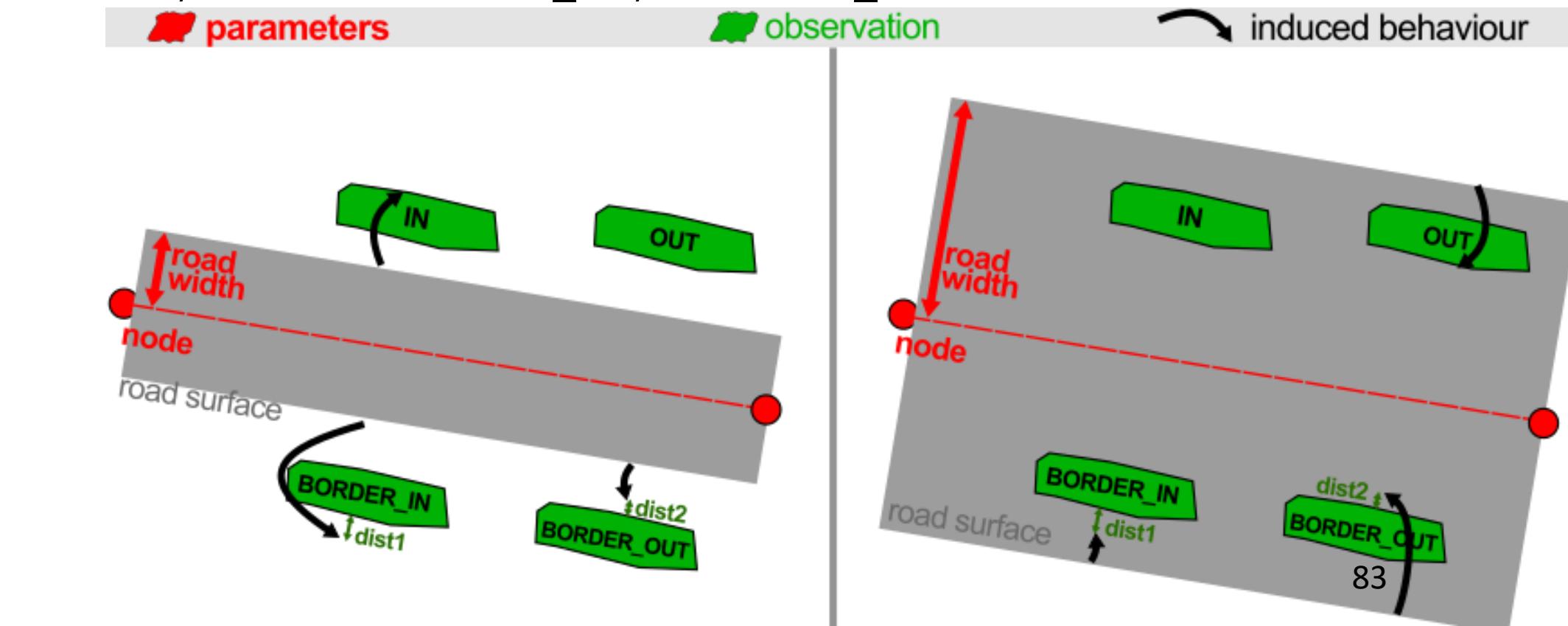
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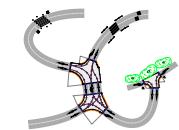


- Observations generate forces on road axis/width
- Each street object type has an expected position:
 - IN/OUT + BORDER_IN/BORDER_OUT + dist

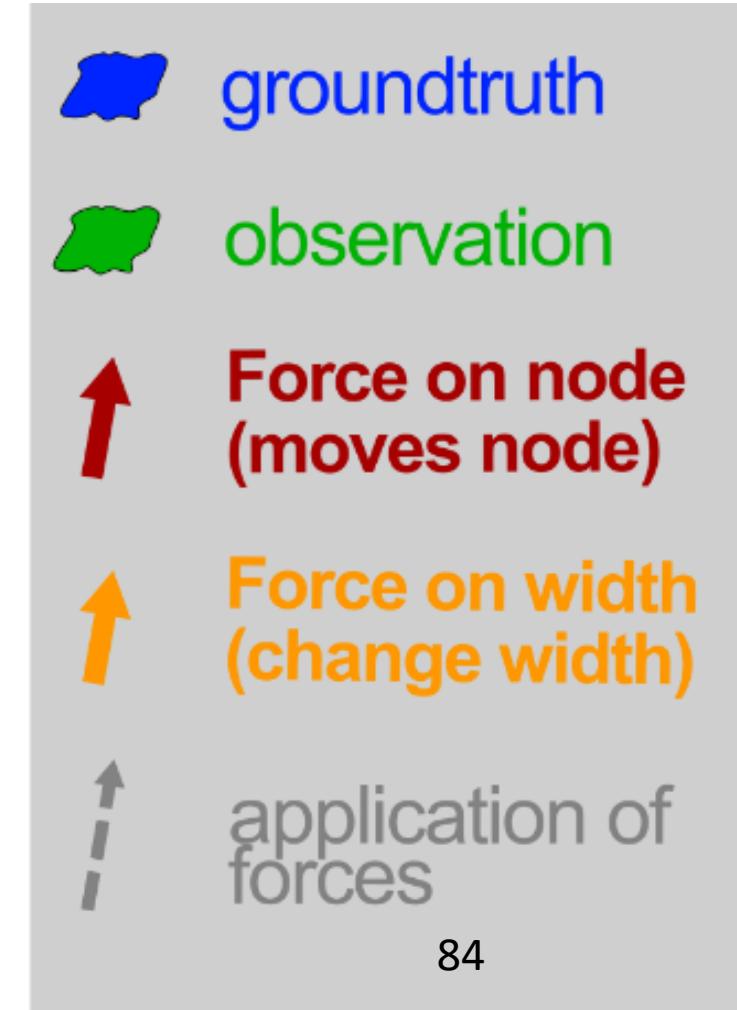
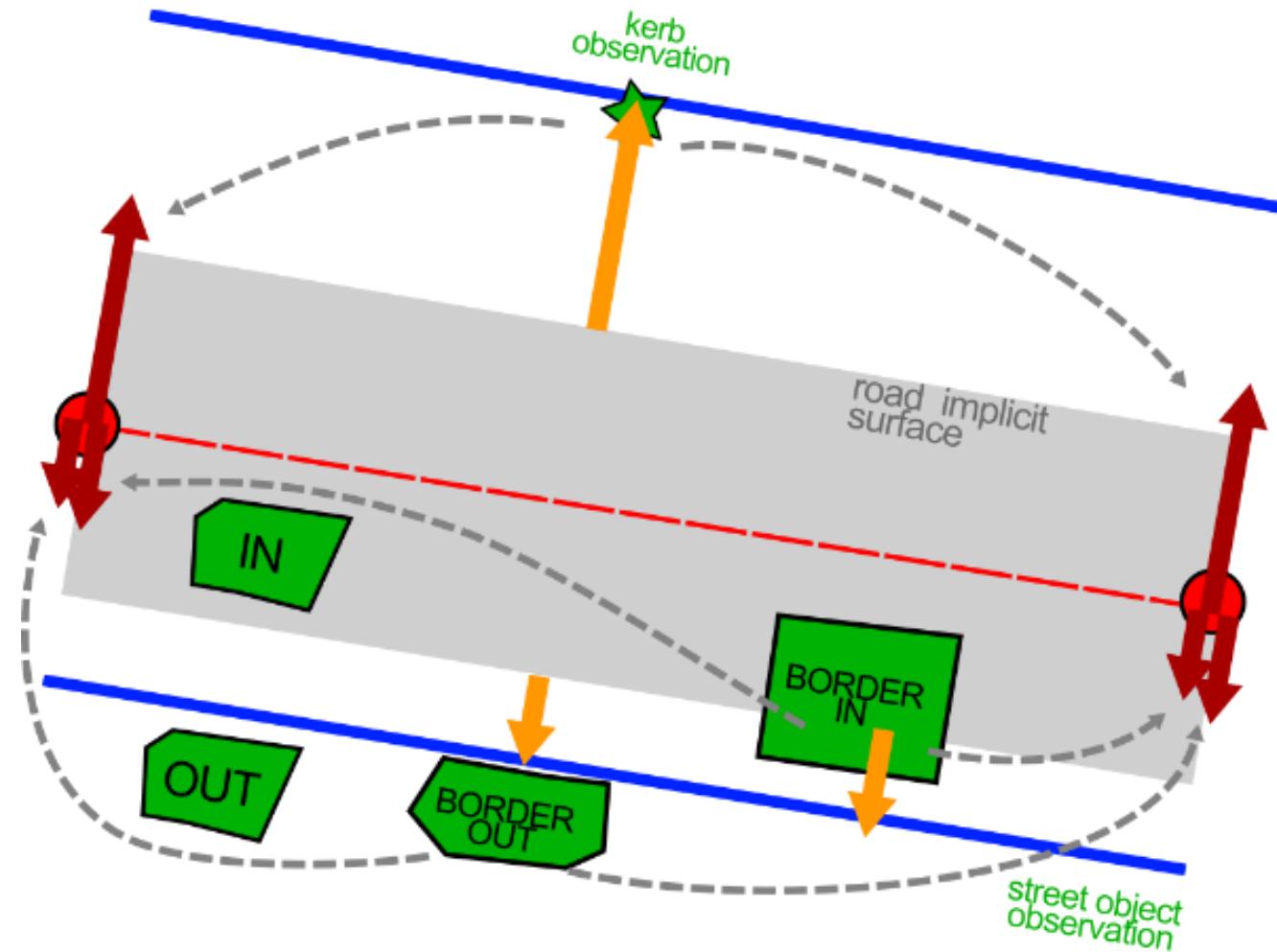


Inverse Procedural modelling: forces

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- So if we sum up forces from observations :



Inverse Procedural modelling: forces

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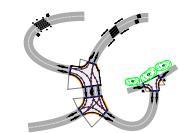
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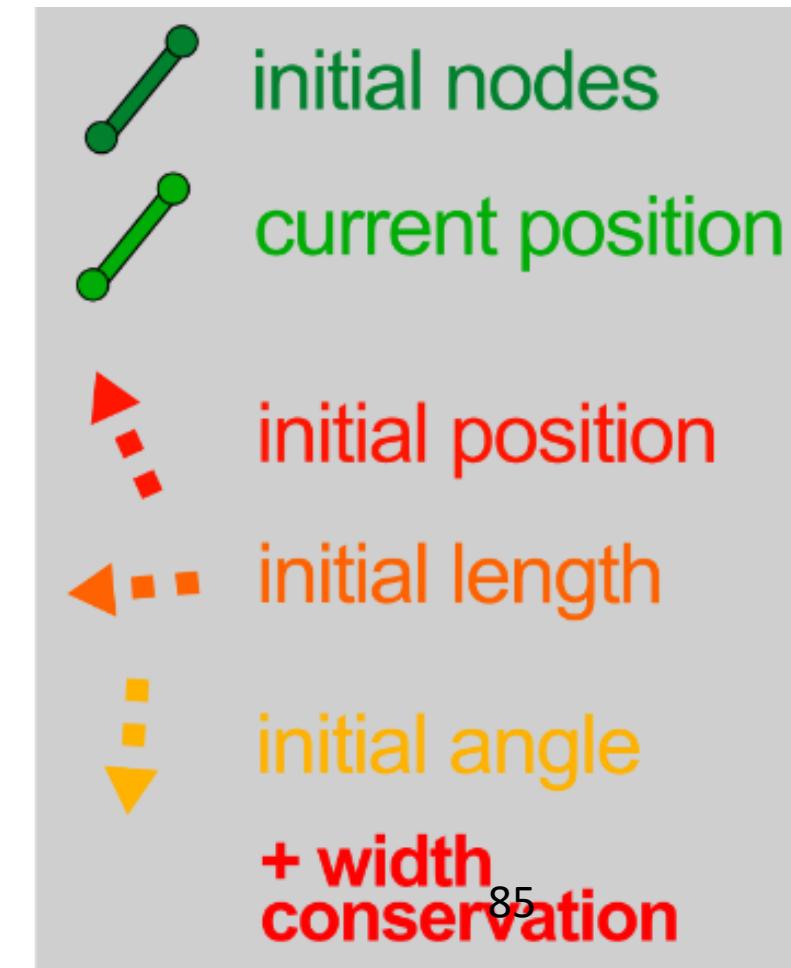
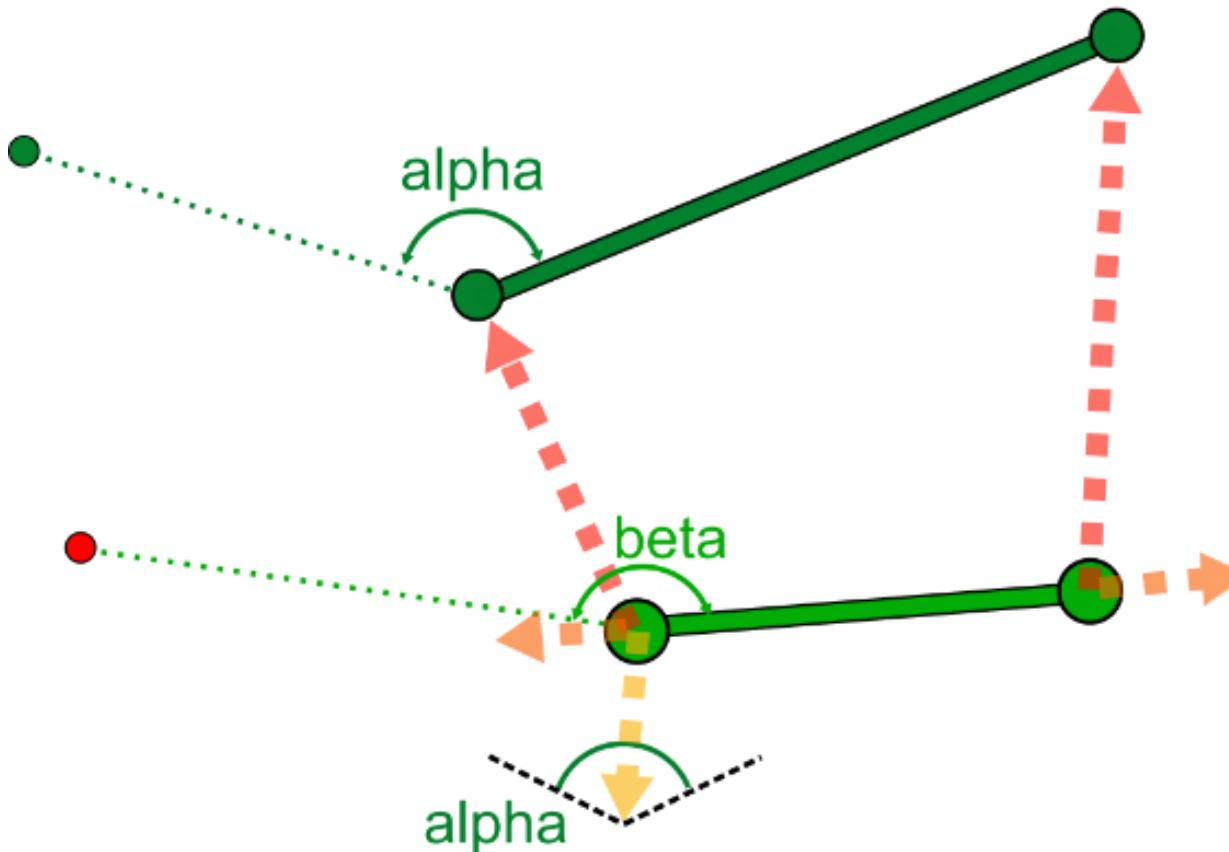
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- Others forces: resisting changes : express confidence in initial road model



Inverse Procedural modelling : matching

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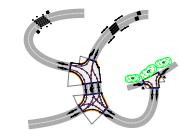
Streets

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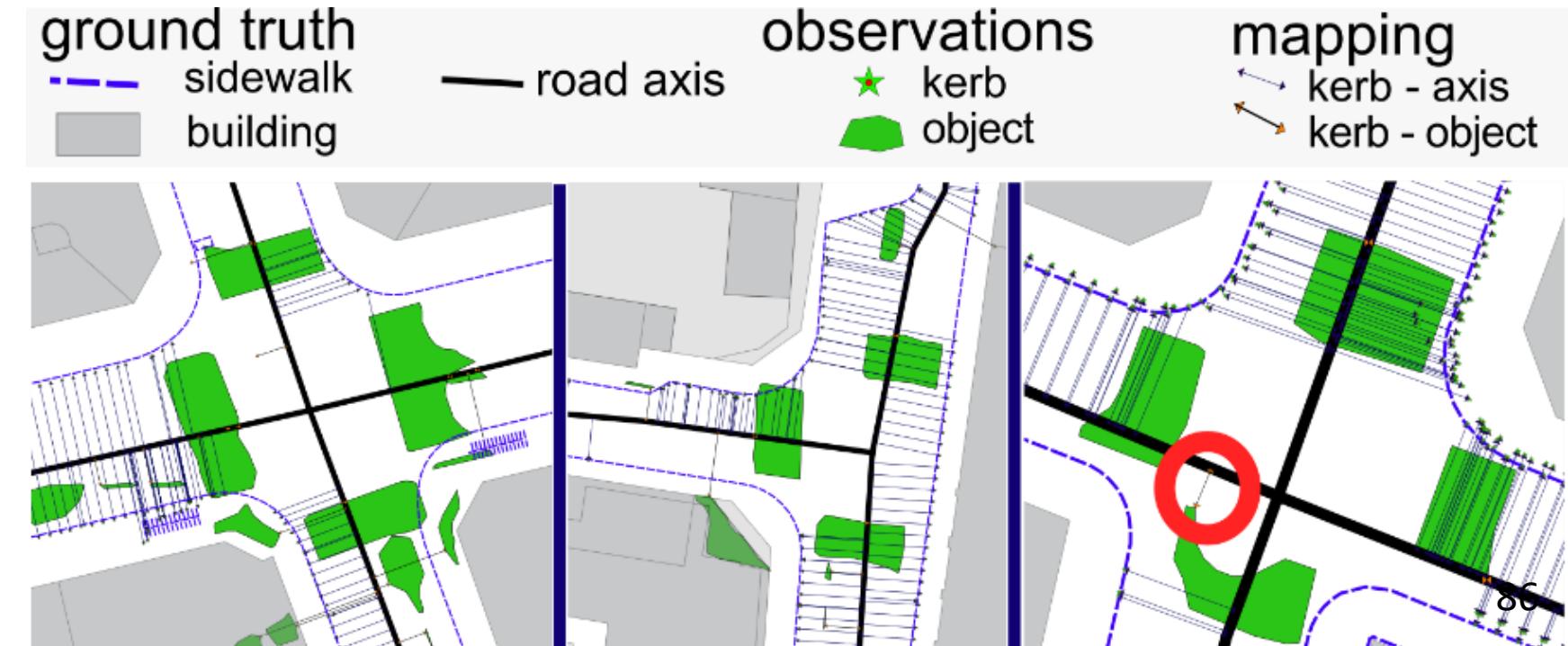
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- Observations generate force on road axis/width,
But first :
- Observation ←matching→ road axis:
- Closest road surface



Inverse Procedural modelling: matching

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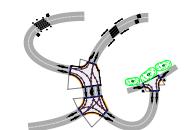
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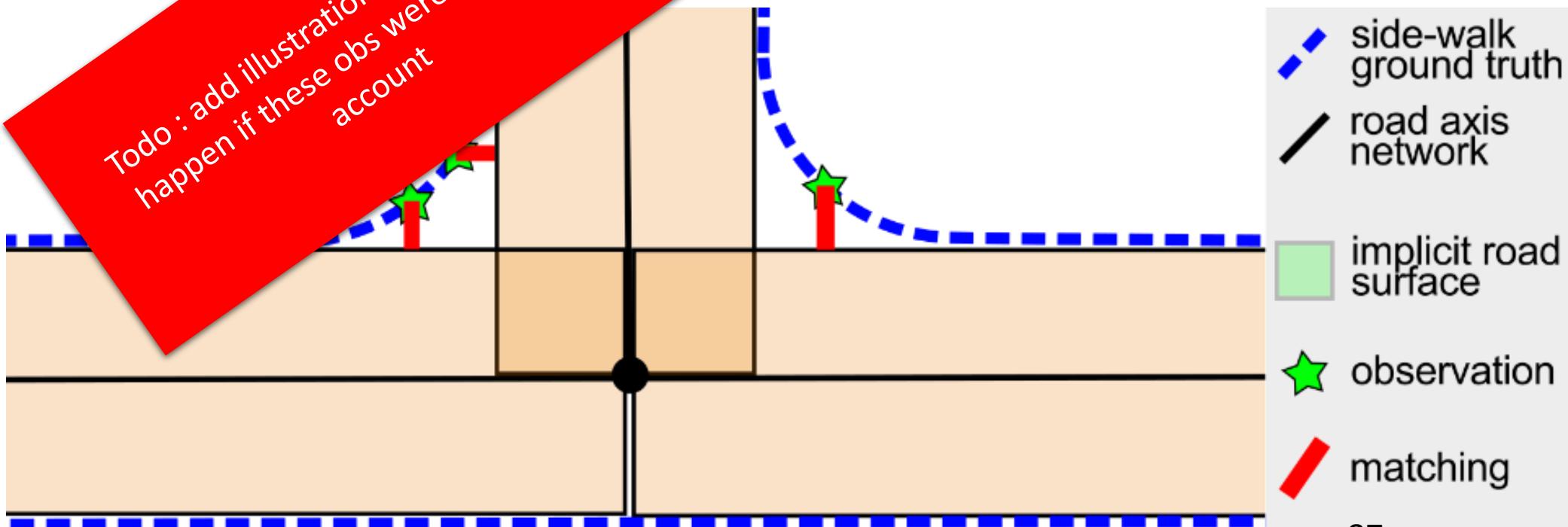
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- In intersection : can't reuse observations:
 - We would need to use full road surface model

Todo : add illustration of what would happen if these obs were taken into account



Inverse Procedural modelling: experiment

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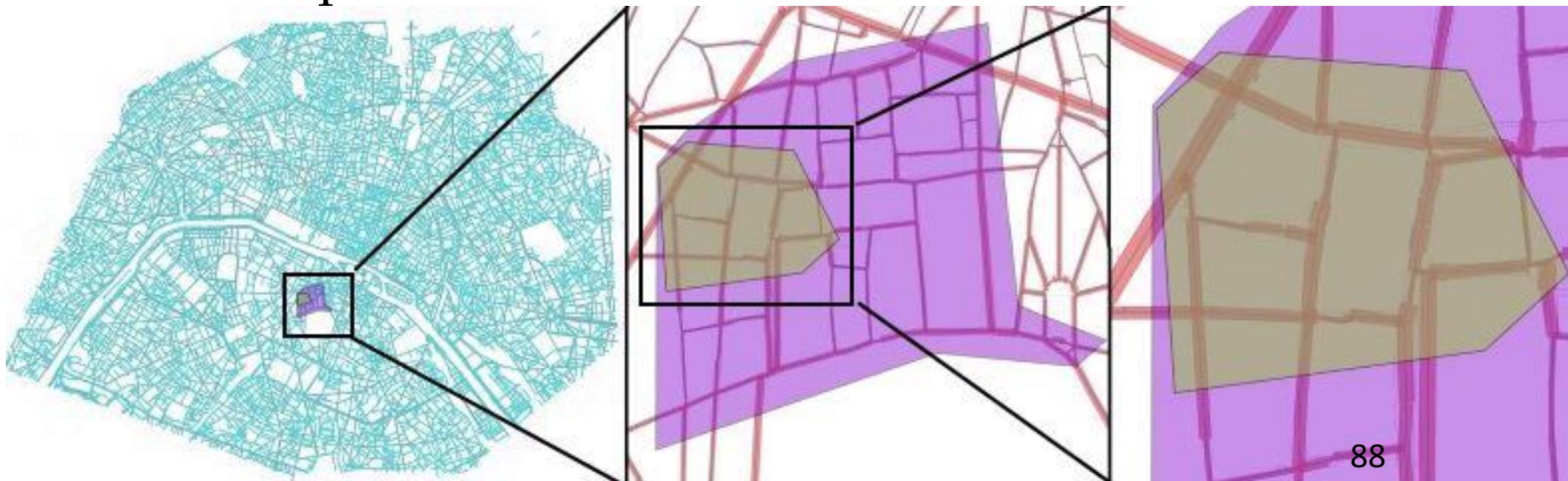
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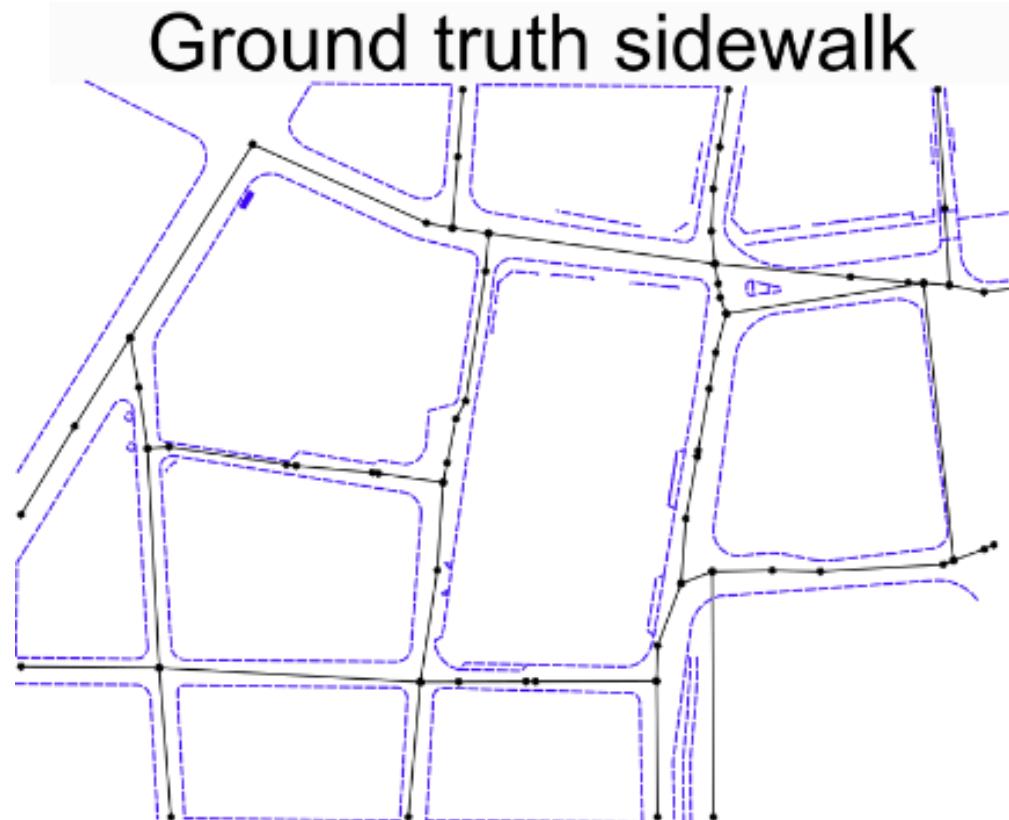


- Optimisation = Non-linear least square
 - → no guarantee to find the optimal solution, robust, very fast
- Open source : [Ceres solver](#)
- Areas of experiment:

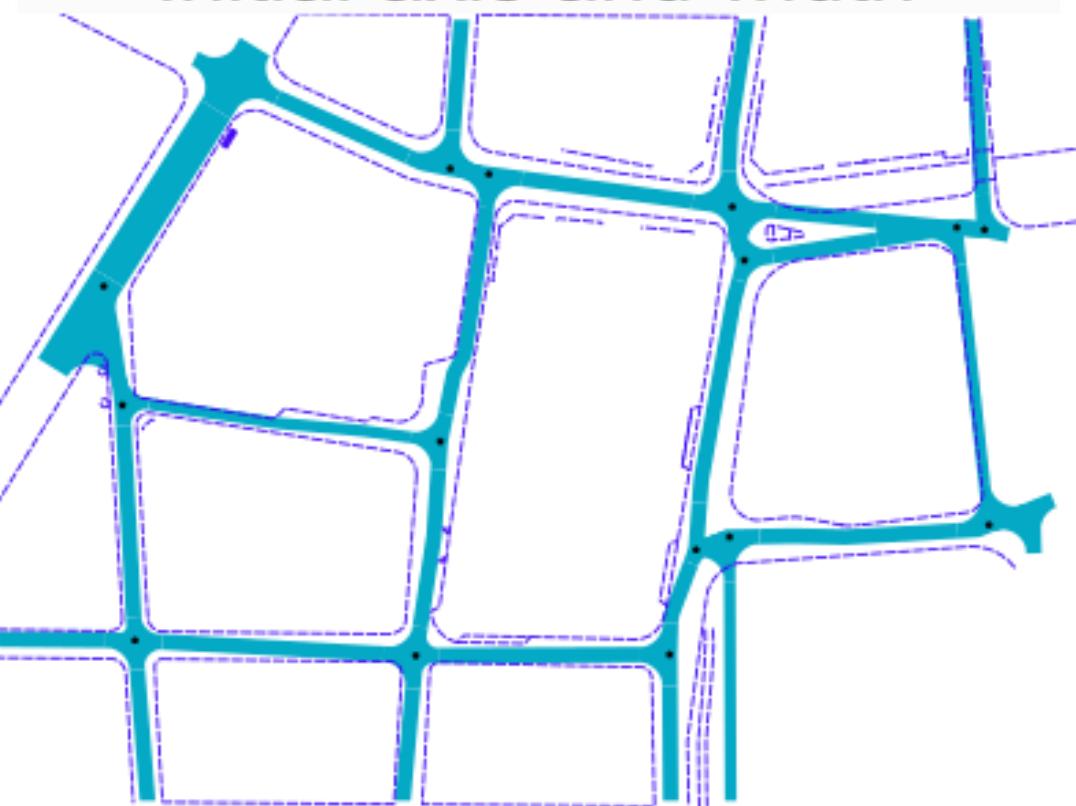


Inverse Procedural modelling : small area

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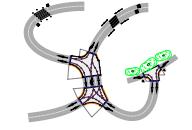


Initial axis and width



Inverse Procedural modelling : small area

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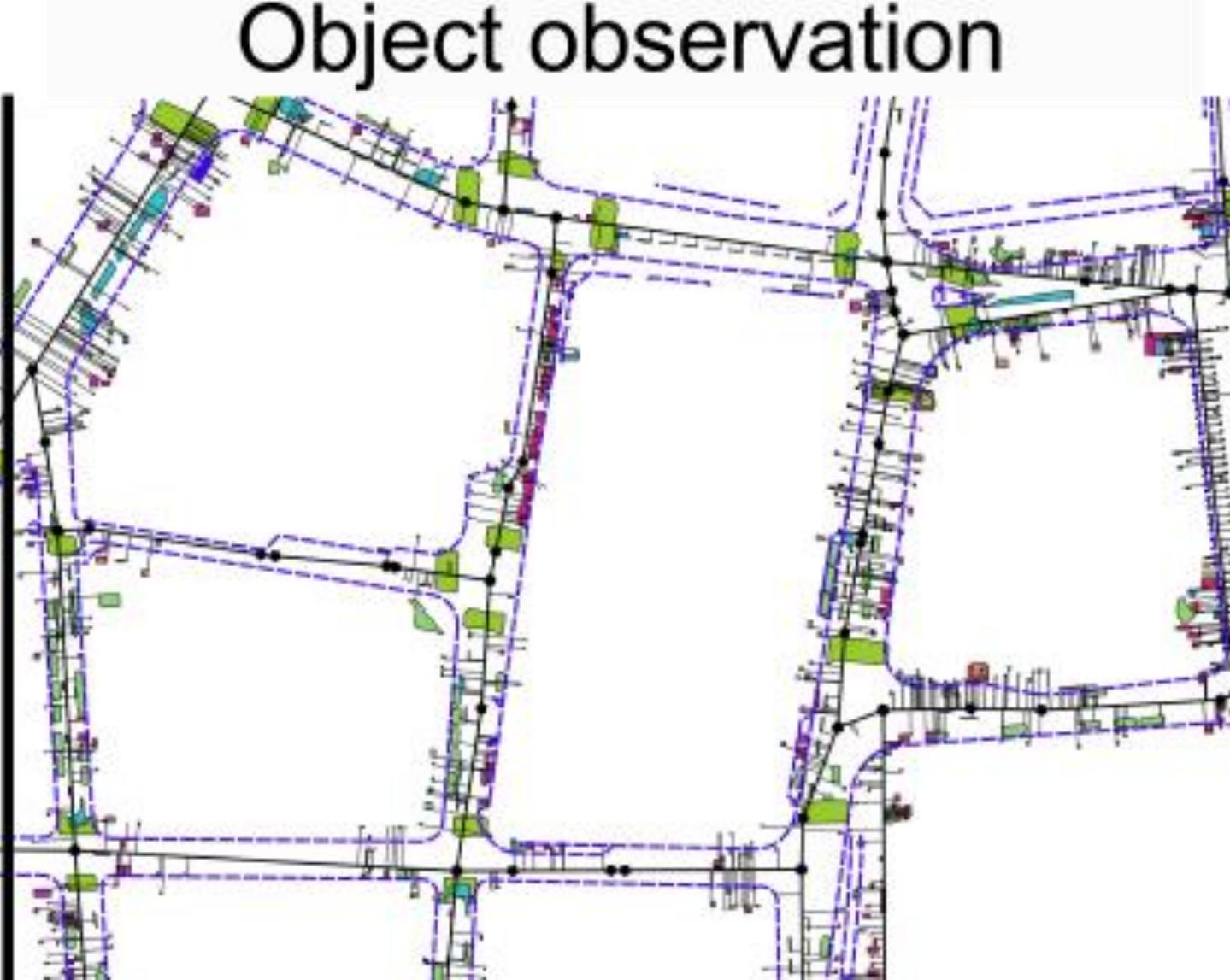
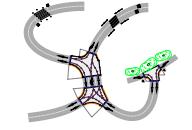


Kerb observation matching



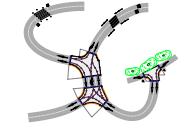
Inverse Procedural modelling : small area

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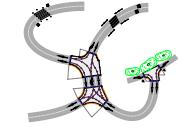


Using Kerb observation



Inverse Procedural modelling : small area

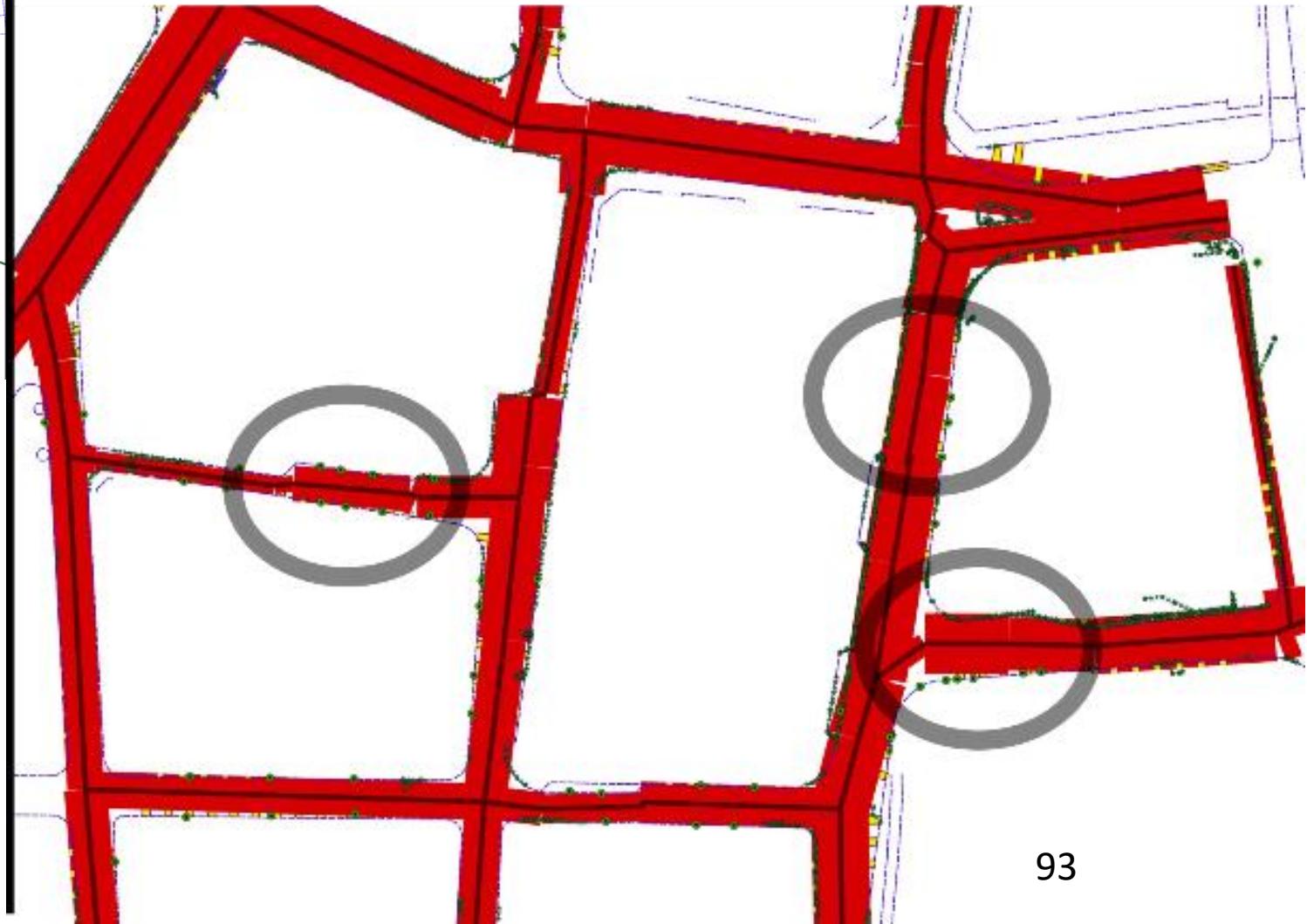
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User defines sidewalk points



Using Kerb and user input



Inverse Procedural modelling : small area

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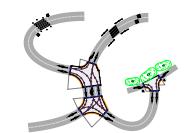
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Conclusion



- Quantitative evaluation:

- Only kerb observation:
 - Median dist to sidewalk : from 1.8m → 0.4m
- Kerb observation + user input
 - Median dist to sidewalk : from 1.8m → 0.34m

It's much better in a challenging area!

Todo : simplify

Inverse Procedural modelling : sensing area

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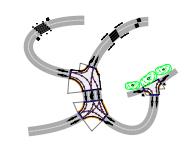
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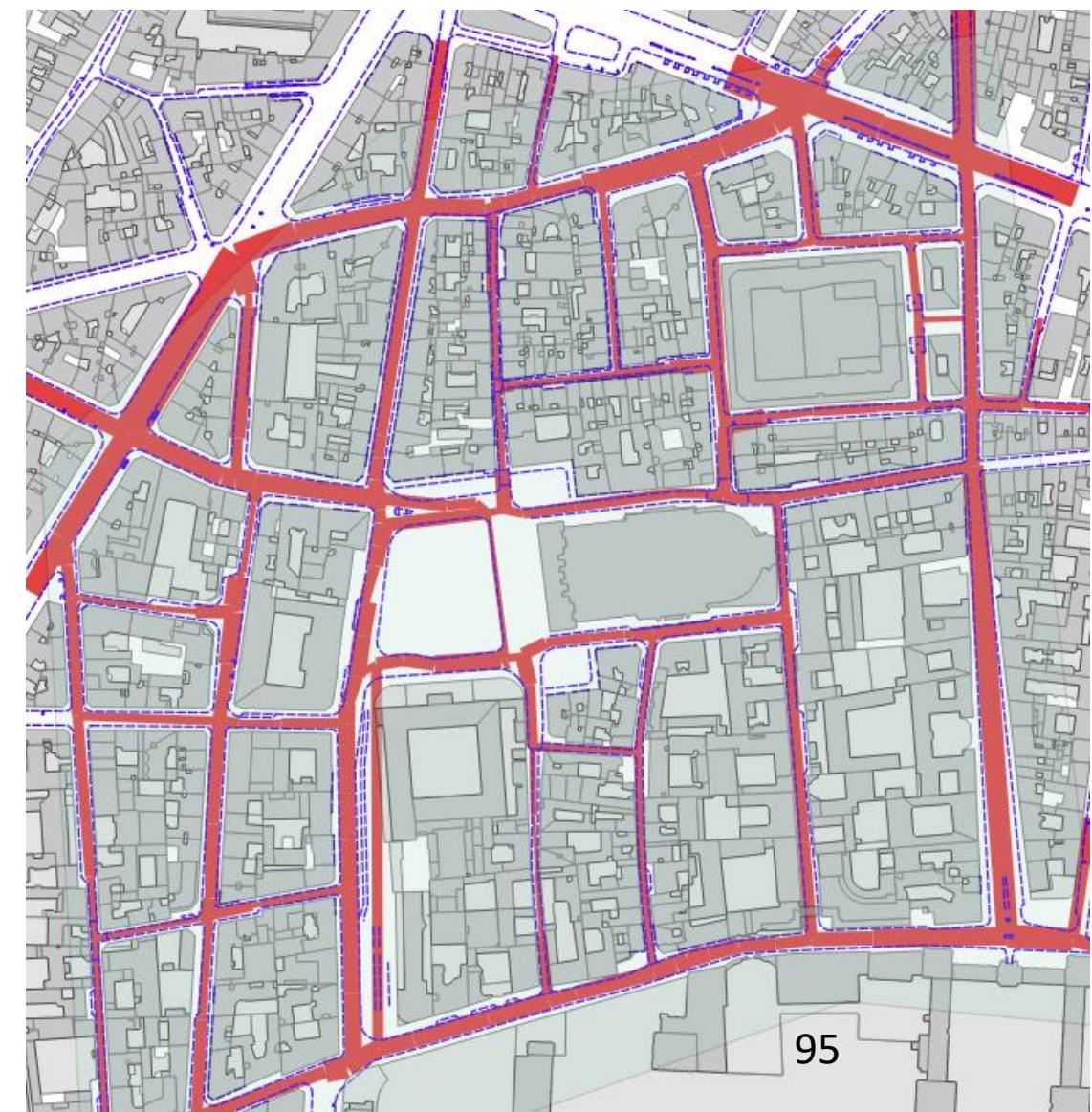
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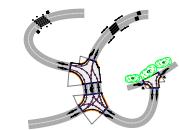


- Whole sensing area:
Results:



Inverse Procedural modelling : sensing area

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- Yellow circle are proportional to error:
- Most of the cases :
 - Not enough curb detection
- Sometime:
 - Road model
- Seldom:
 - Optimization

Todo : simplify



Inverse Procedural modelling : sensing area

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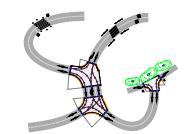
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- Quantitative evaluation:
- Only kerb observation:
 - Median dist to sidewalk : from 1.5m → 0.6m

Many streets in the area lack kerb observations, but significantly better.

Todo : simplify

Inverse Procedural modelling : Paris area

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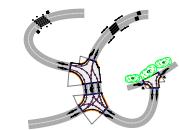
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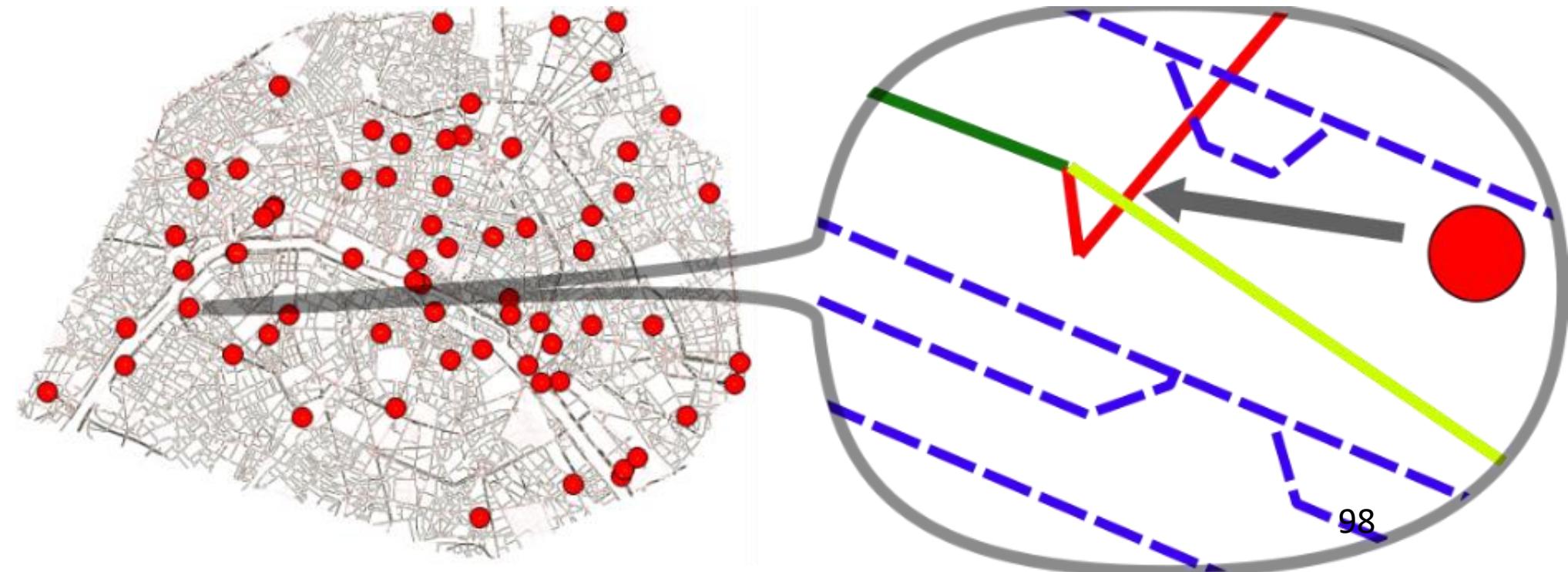
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- Whole Paris : topology is broken at few points
 - Few enough to manually correct



Inverse Procedural modelling: Paris area

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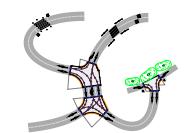
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- Quantitative evaluation:
- Using ground truth as observation
 - Median dist to sidewalk : from 1.5m → 0.1m

still residuals, why?

Todo : simplify

Inverse Procedural modelling: error sources

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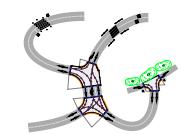
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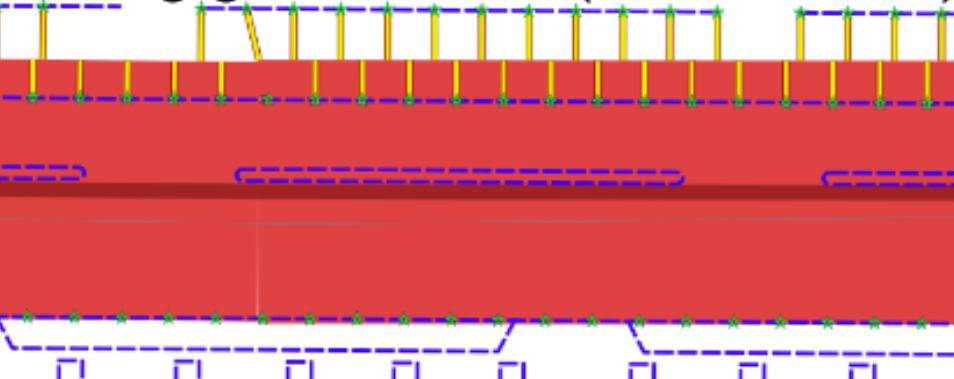
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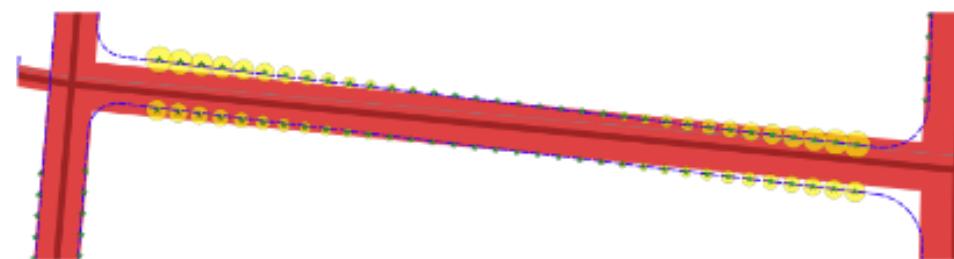


- Residual sources

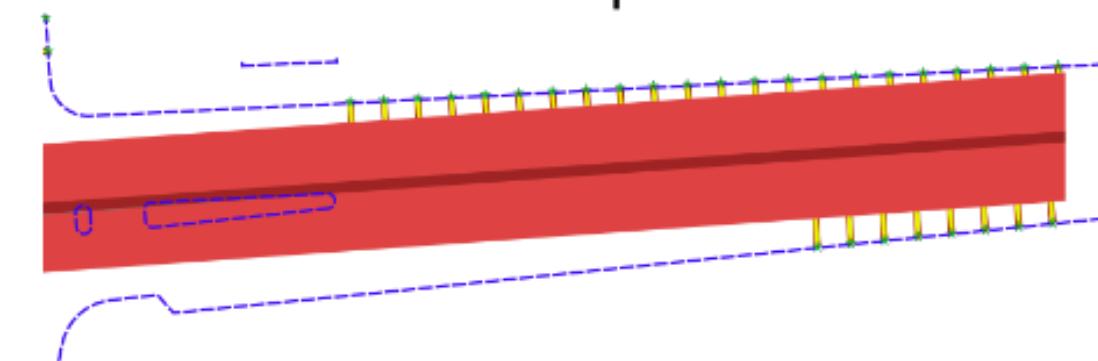
Wrong ground truth (blue dashes)



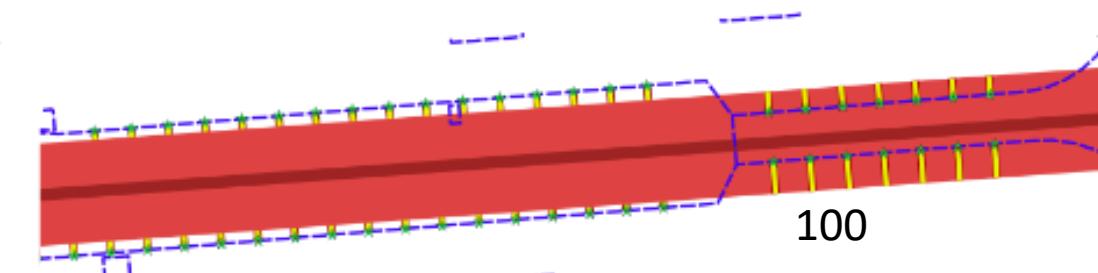
Over constrained (not enough split)



Road model too simple



Over constrained (not enough split)



Inverse Procedural modelling: Streetgen on optim

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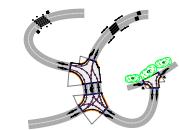
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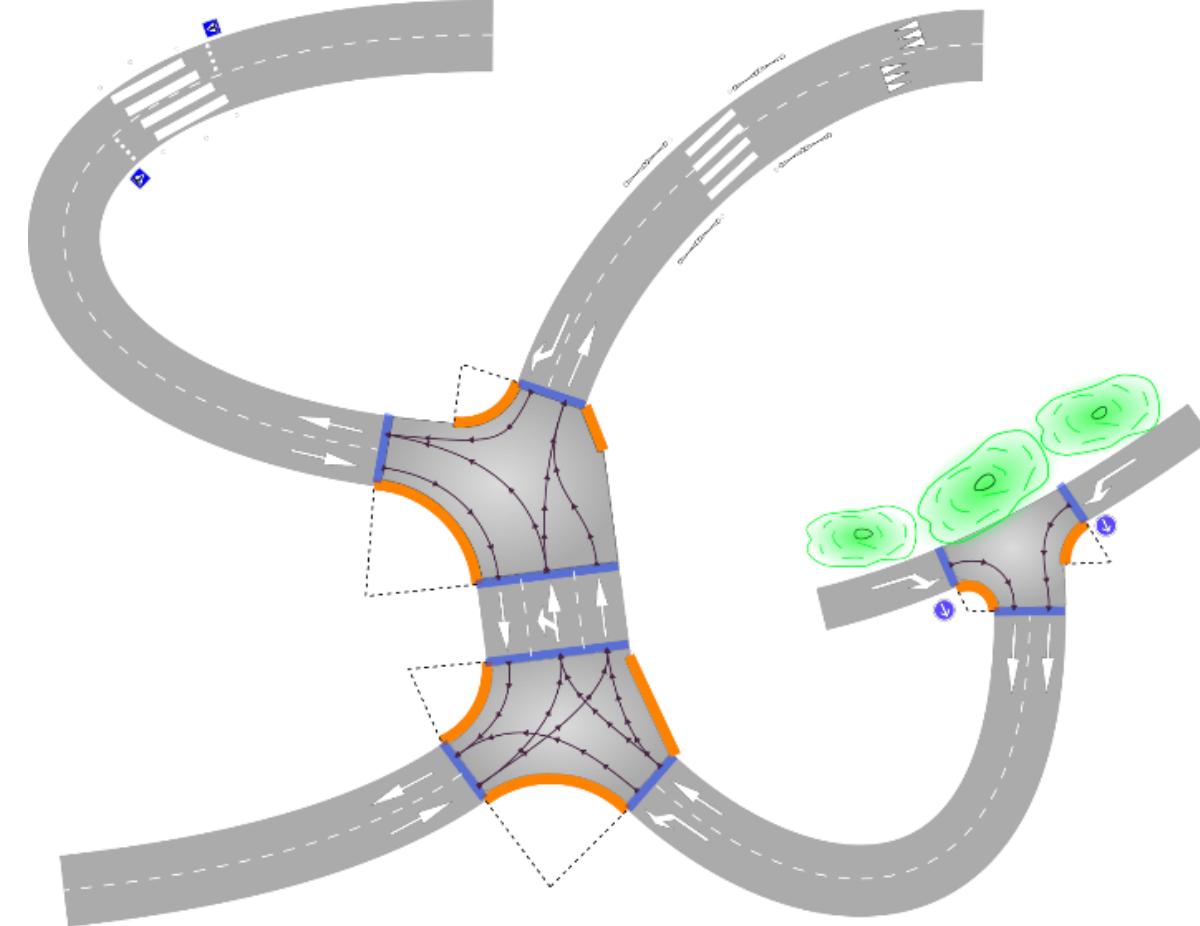
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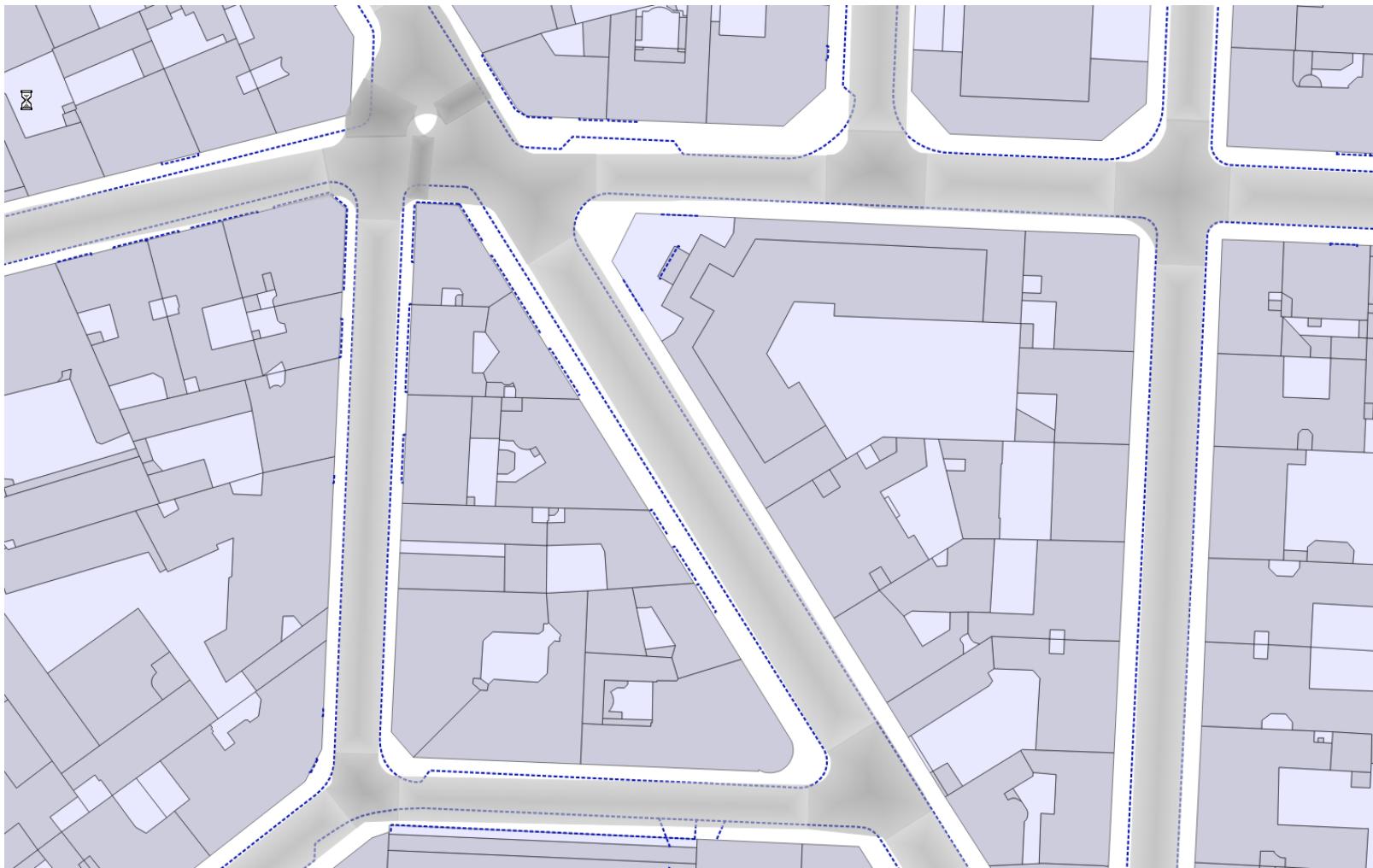
- Once simple road model is optimised,
we can generate streets with StreetGen



Inverse Procedural modelling: Streetgen on optim

edge id=15; next_l=16
end_node=3 ...

- Streetgen after optimisation



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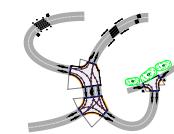
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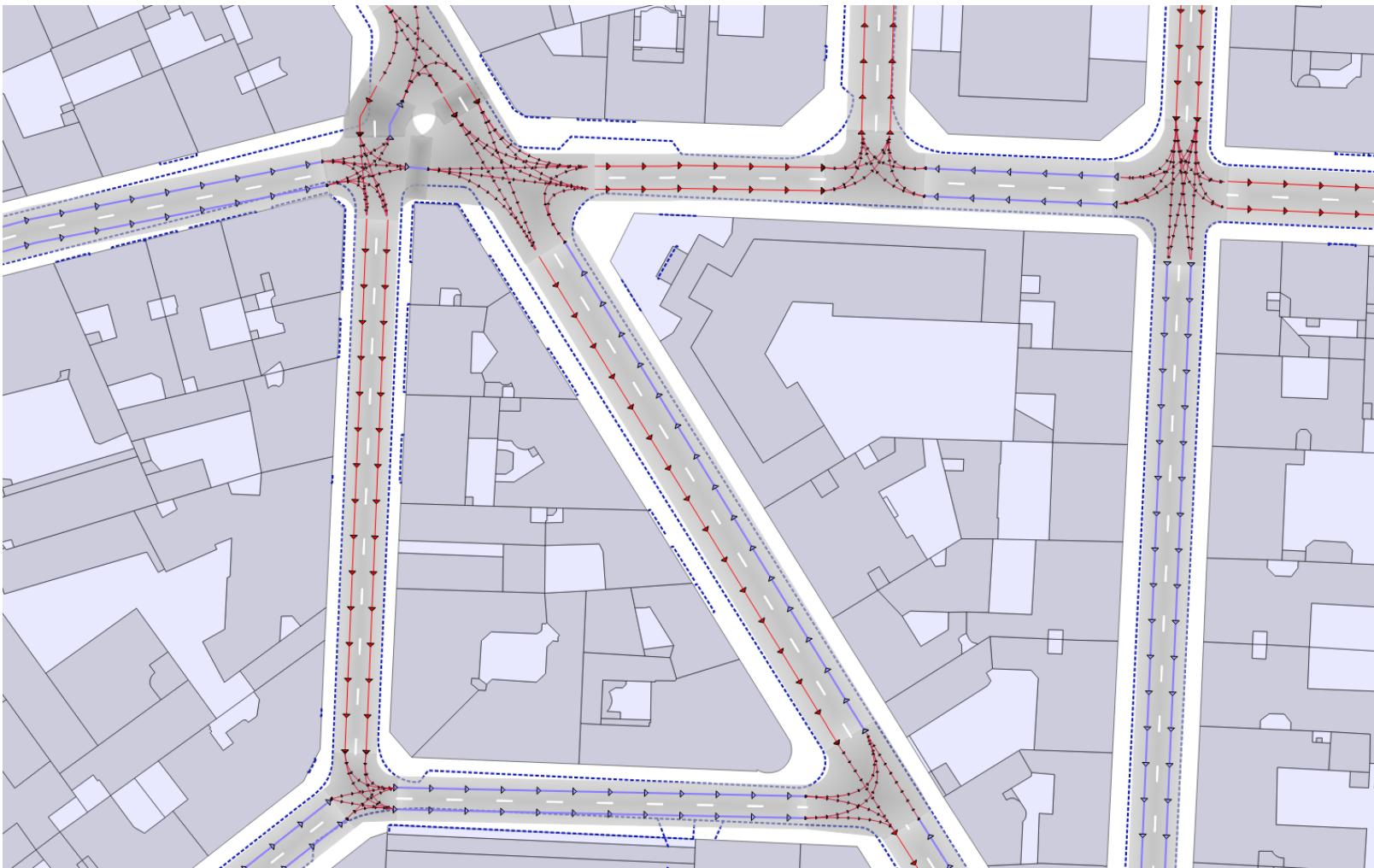
Conclusion



Inverse Procedural modelling: Streetgen on optim

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- Traffic information is generated (but has not been optimised)



Inverse Procedural modelling: Limitations

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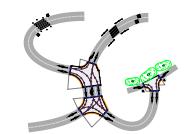
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Conclusion



- (Many) Limitations
 - Road model is too simple
 - Constant number of parameters in optim
 - For the moment, objects are almost useless
 - Lacking regularisation forces for width (propagation)
 - Must choose between trusting initial model and trusting observations
 - How to deal with parking places?

width= 8; lane= 3

width= 6; lane= 2

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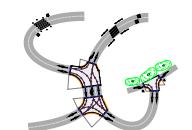
Conclusion

width= 4; lane= 1

Data for observations: Point Cloud Server

Short introduction to Lidar

Point Cloud Server



StreetGen : Inverse procedural modelling

width= 8; lane= 3

width= 6; lane= 2

Demo Live mobile mapping Lidar (Velodyne)

Intro

State of the Art

StreetGen

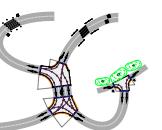
Streets

Interaction

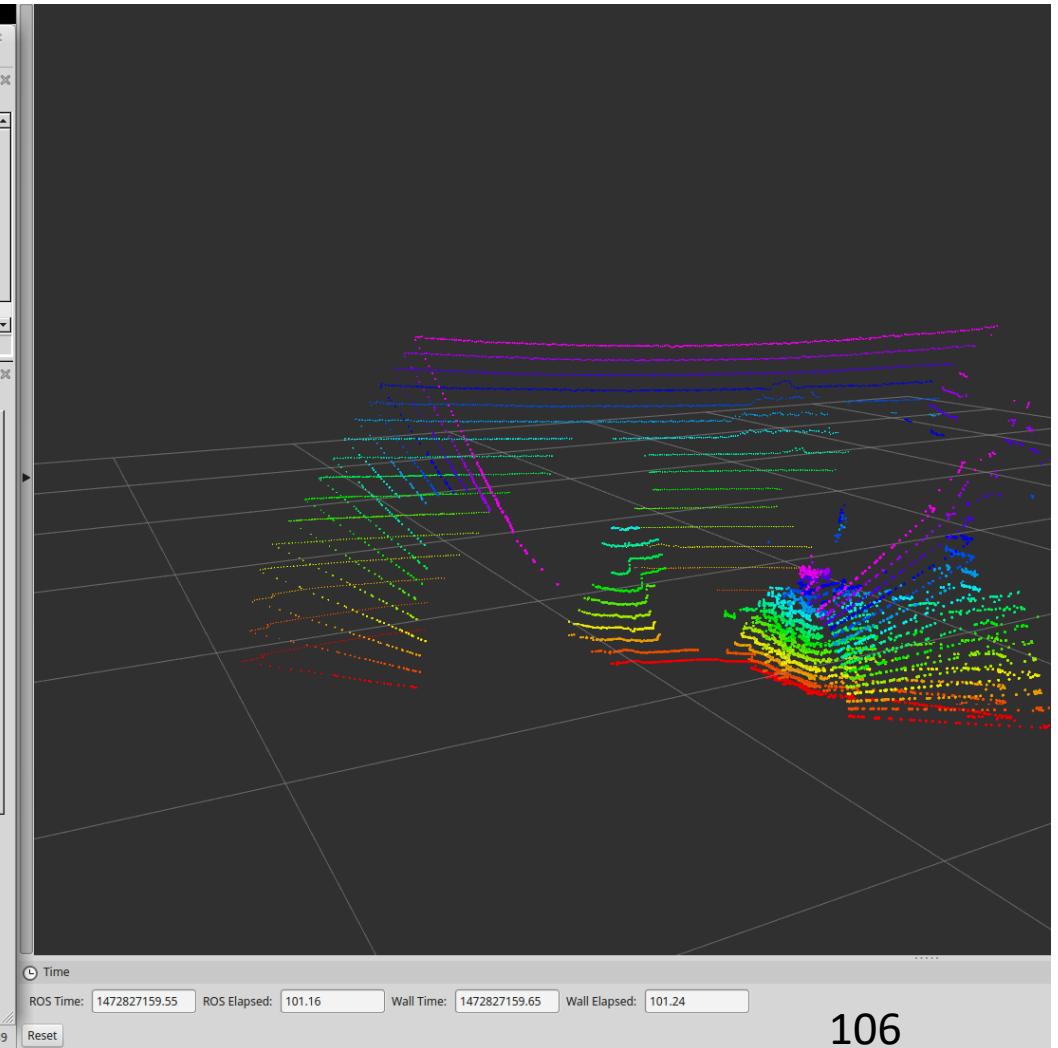
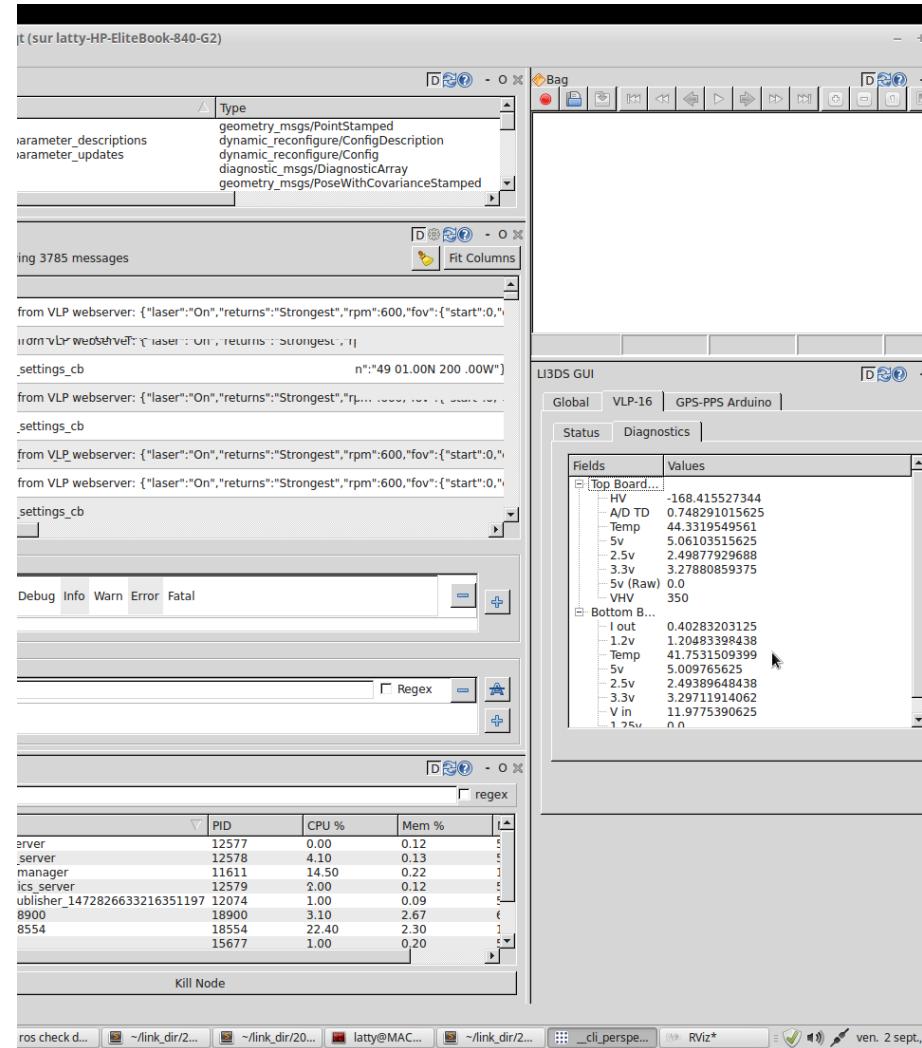
Automation

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width= 4; lane= 1



width= 8; lane= 3

width= 6; lane= 2

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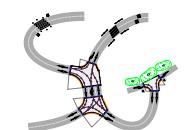
Conclusion

width= 4; lane= 1

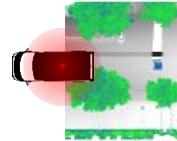
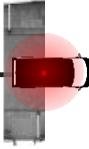
Data for observations: Point Cloud Server

Short introduction to Lidar

Point Cloud Server



Point Cloud Server



Intro

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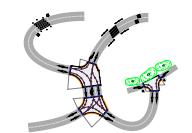
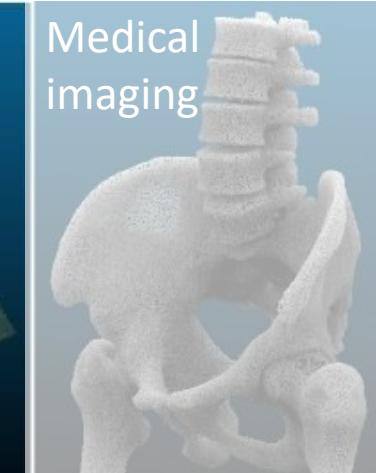
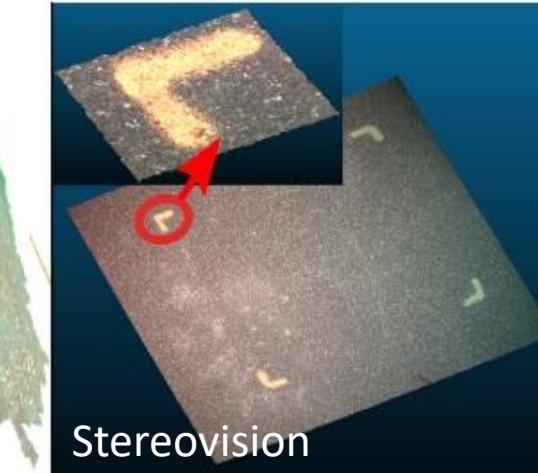
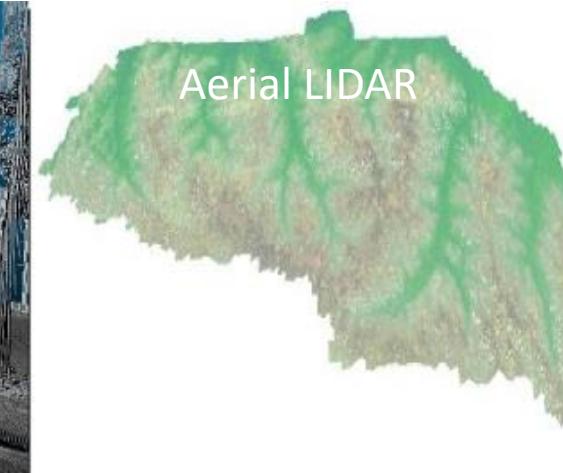
Streets

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Point Cloud Server: Problems

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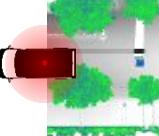
Streets

Interaction

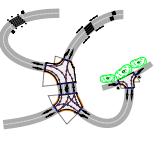
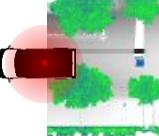
Automation

P.C. Server

Conclusion



- Problem:
 - Massive data → need
 - Sharing
 - Filtering
 - Efficient I/O
 - Compression
 - Very specific for various purposes
(many tools/format/usage)
 - Point cloud != only processing
 - need to manage the entire pipeline
 - need meta data / contextual information
 - cross use with other data



Point Cloud Server: State of the art

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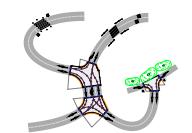
Streets

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- File-based
 - Simple, no concurrency
 - Can't do much with points
- DBMS (point storing)
 - Powerful
 - Can't scale
- NoSQL
 - Scale well
 - Specific and tailored
- Cloud
 - Ultimate scaling
 - Theoretical problem with indexing
- DBMS (group of points storing)
 - All inclusive
 - Points need to be group-able



Otepka et al., 2013

Rieg et al., 2014

van Oosterom et al., 2015

Managing
billions of nD-
points : difficult !

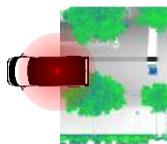
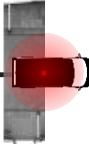
≠

Managing **millions** of
groups of points: easy!

Greyhou

Todo : simplify, images

Point Cloud Server: Method



- Idea:

PCS = a ... server !

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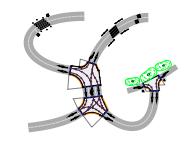
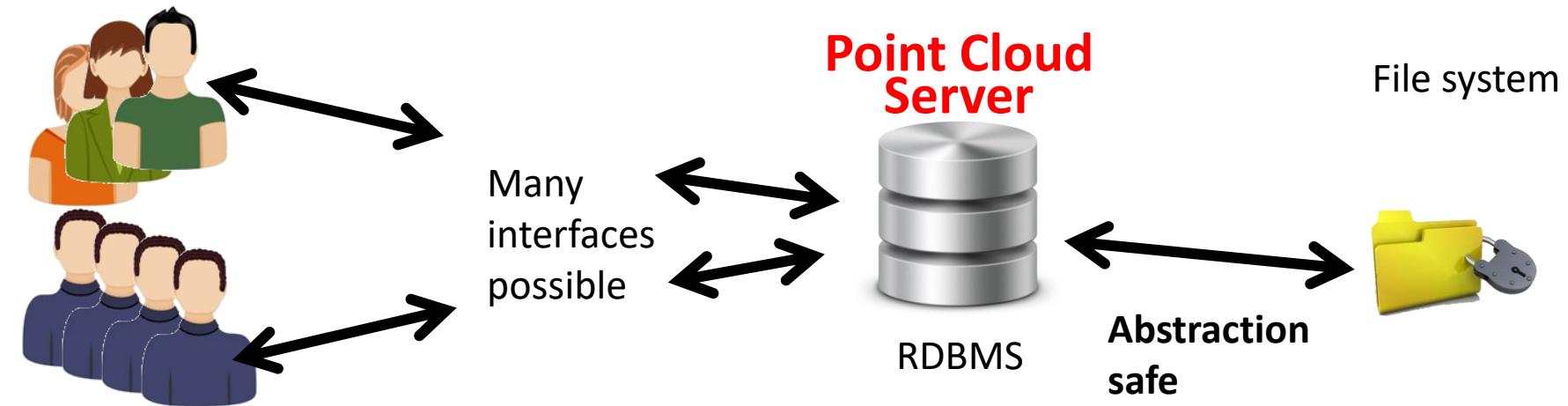
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Point Cloud Server: Method

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- Workflow

LOAD

- server reads
- client sends

EXPORT

- server sends
- client reads
- point streaming
- point cloud files as a service

RDBMS

METADATA

- secure and relational
- extended (trajectory, sources)
- generalisation/vis.

PROCESSING

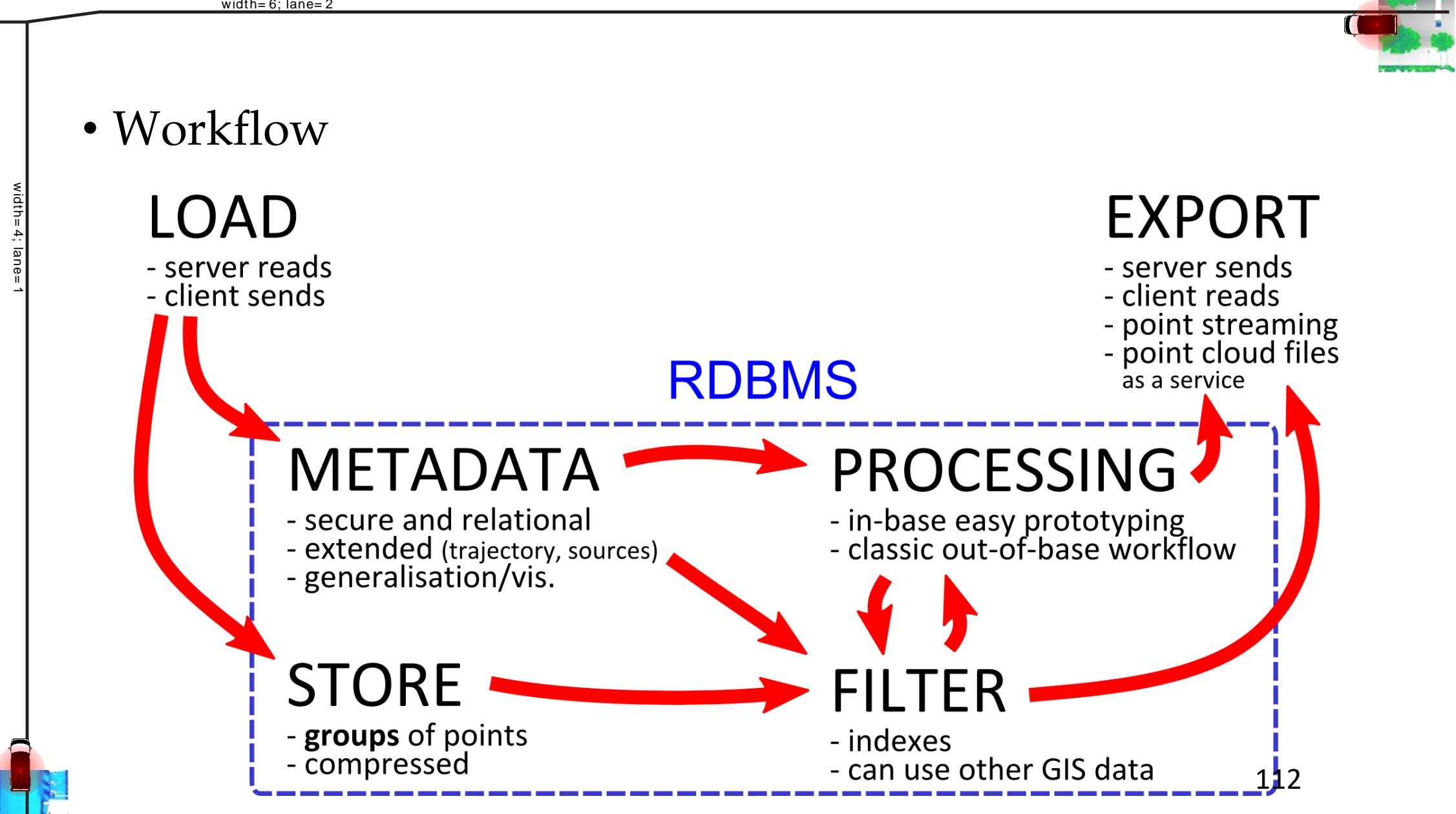
- in-base easy prototyping
- classic out-of-base workflow

STORE

- groups of points
- compressed

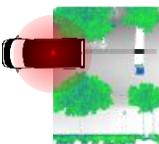
FILTER

- indexes
- can use other GIS data





Point Cloud Server: Method

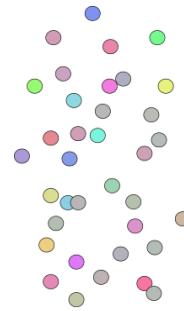


- Main idea about storing

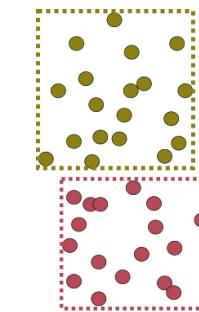
1 point =

GPS_time (s)	X (m)	Y(m)	Z(m)	reflectance (....)
54160.295	2068.230	20690.025	45.934	-9.4497
(....)				

1 row = 1 point
Analogy : Pixels



1 row = N points
Analogy : Image



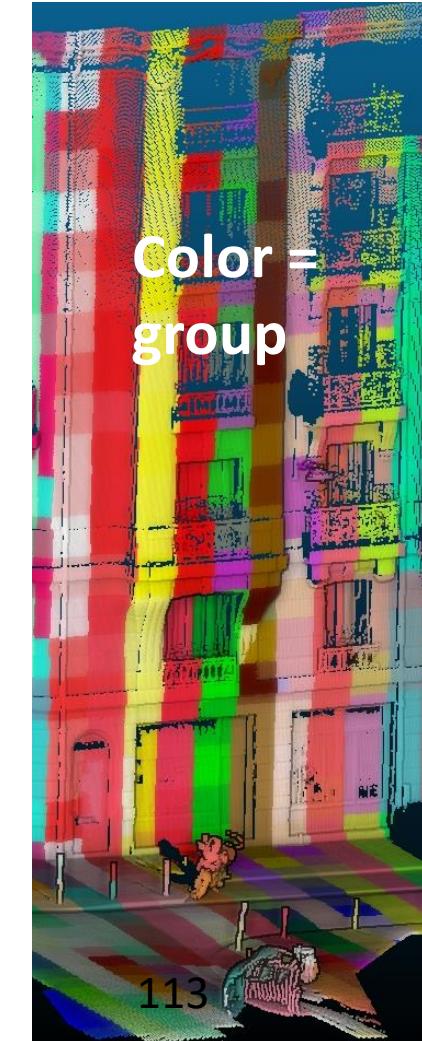
Billions
points



Million
groups



Usage : do we really need
to get points 1 by 1?



Point Cloud Server: Loading/Exporting

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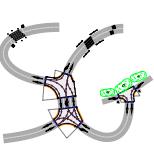
Streets

Interaction

Automation

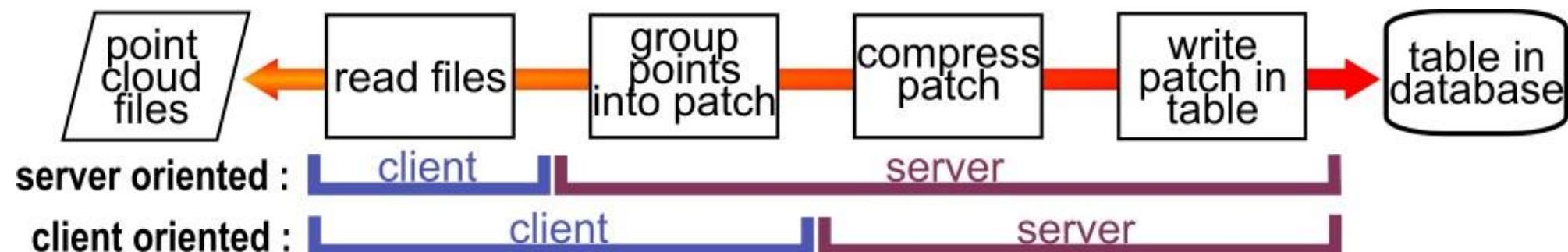
P.C. Server

Conclusion



width=6; lane=2

- Loading/exporting points into the PCS:
 - 2 flavors : how much does the server work?



Point Cloud Server: Loading/Exporting



Paris

- Terrestrial lidar
- 2.15 B points
- 750 ply files
- 42 linear km
- 21 attributes
- Typical resolution: 1 cm

Point Cloud Server: Loading/Exporting



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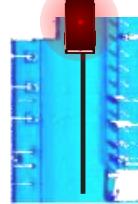
Streets

Interaction

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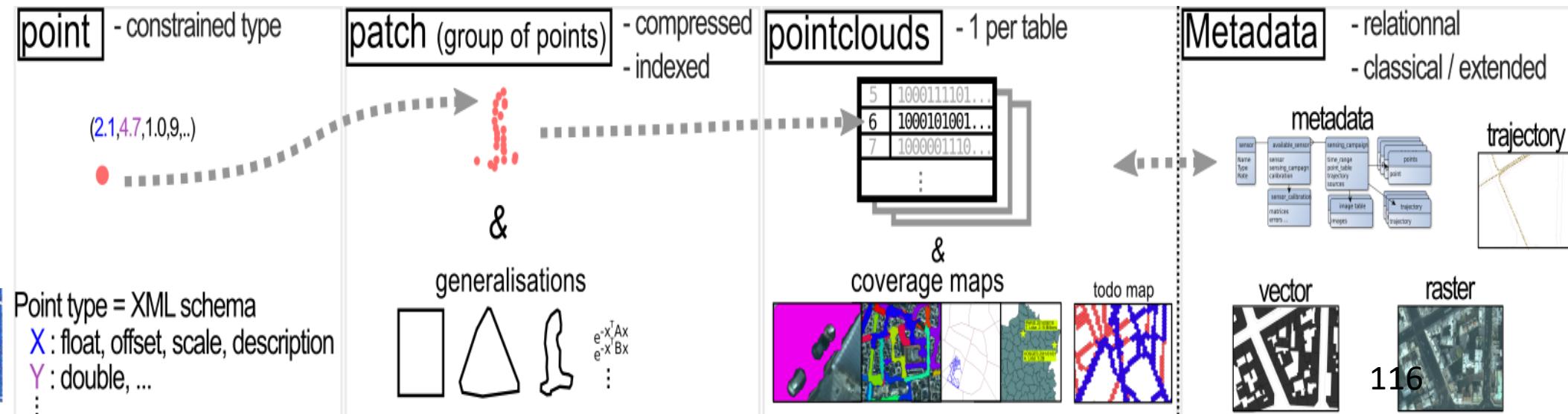
P.C. Server

Conclusion



- Paris loading speed: 75k pts/s writing : 200k pts/s
 - Not far from actual sensing speed
 - Could be faster ([Vanoosterom2015](#))

- We load point clouds, but how are they stored?



Point Cloud Server: generalisation



- Group of points (aka patch) generalisation
 - Generalisation = abstraction

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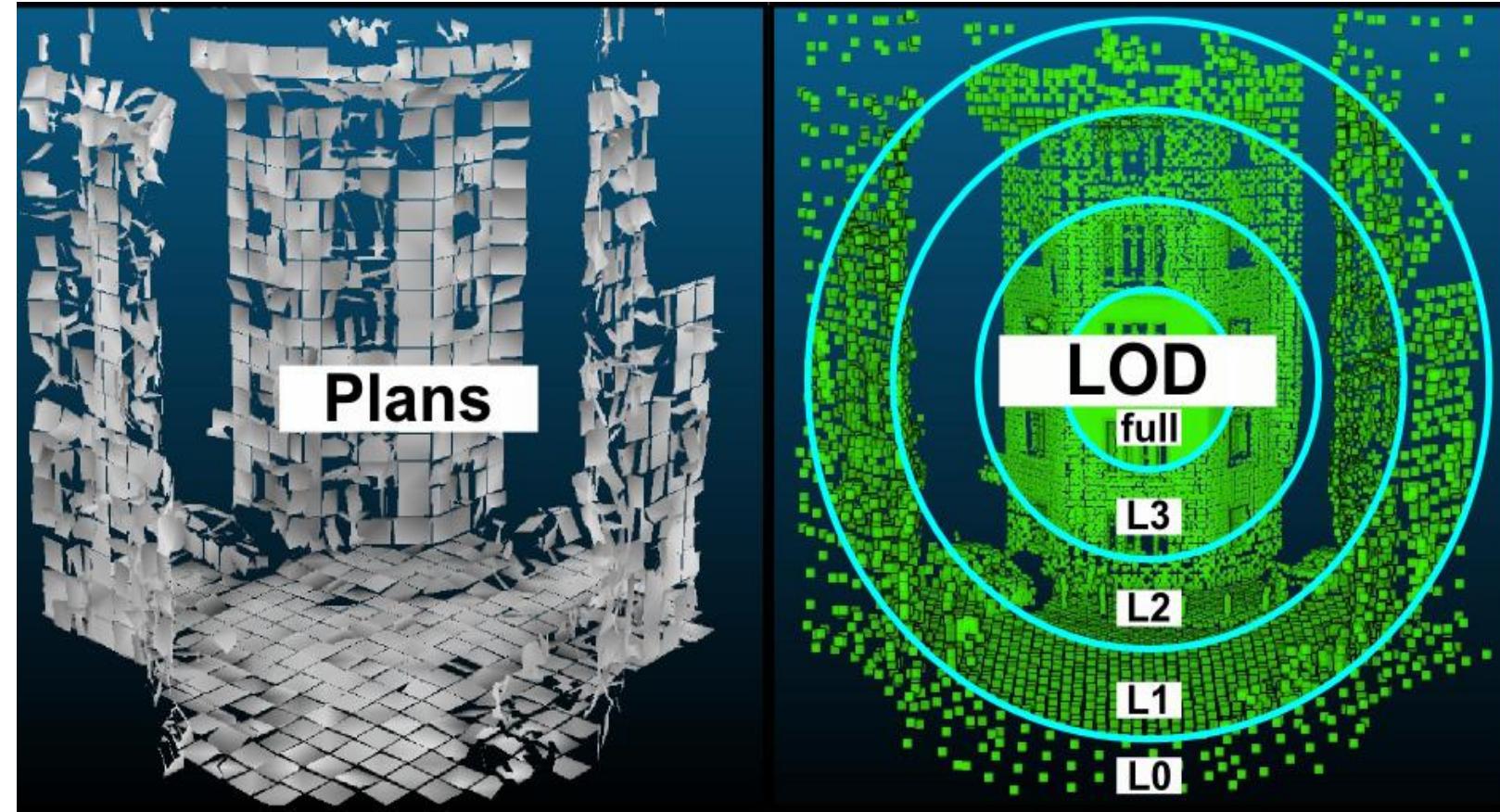
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width=4; lane=1



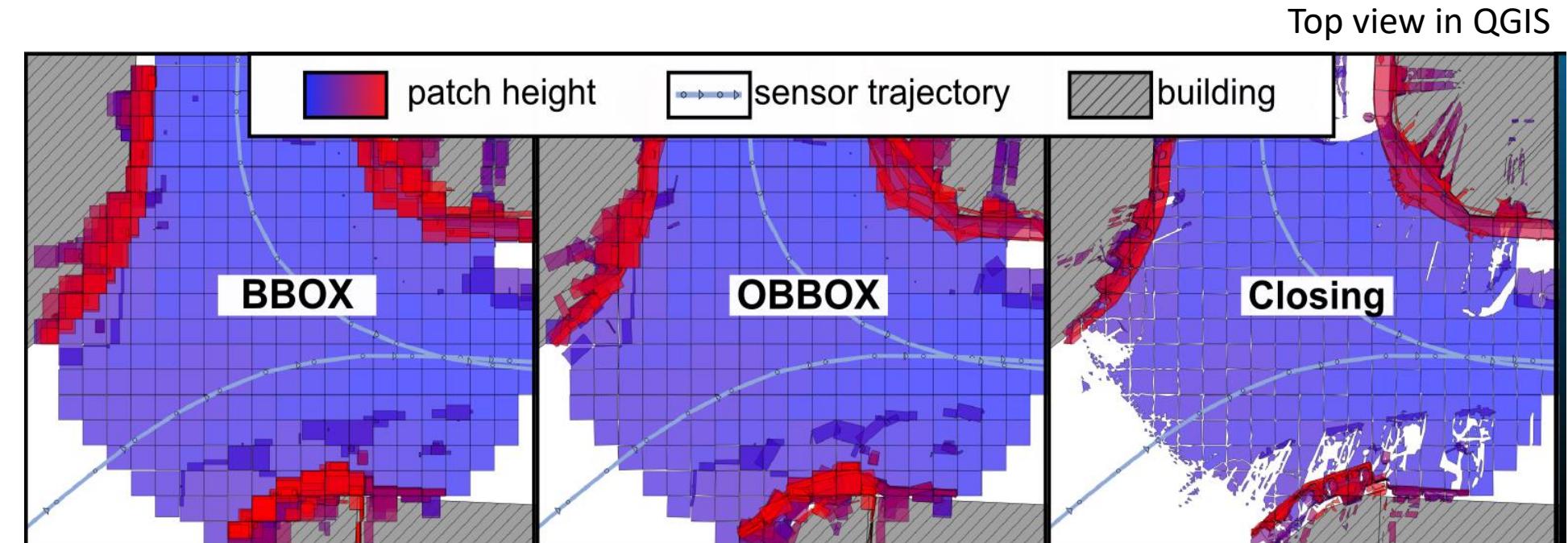
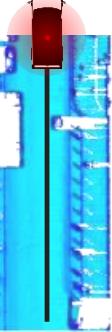
Point Cloud Server: generalisation



- Other generalisation

- Essential : abstracting the data = more abstract usage
- Ex : points within flat neighborhood vertical VS points in a wall

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Point Cloud Server: processing



- More generalisation

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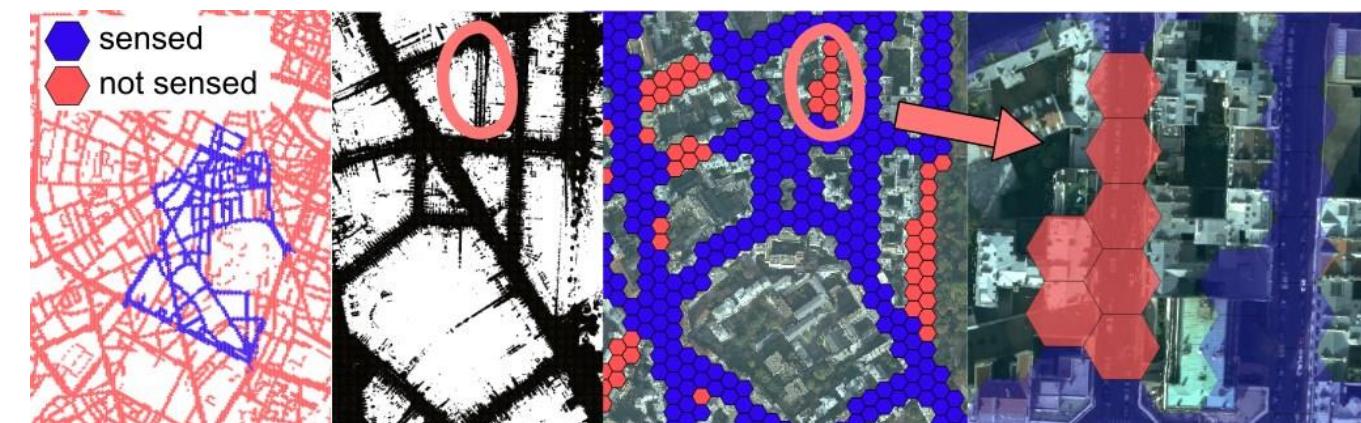
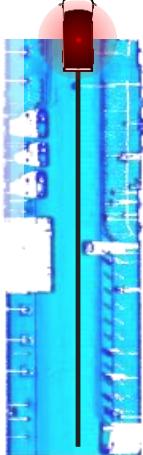
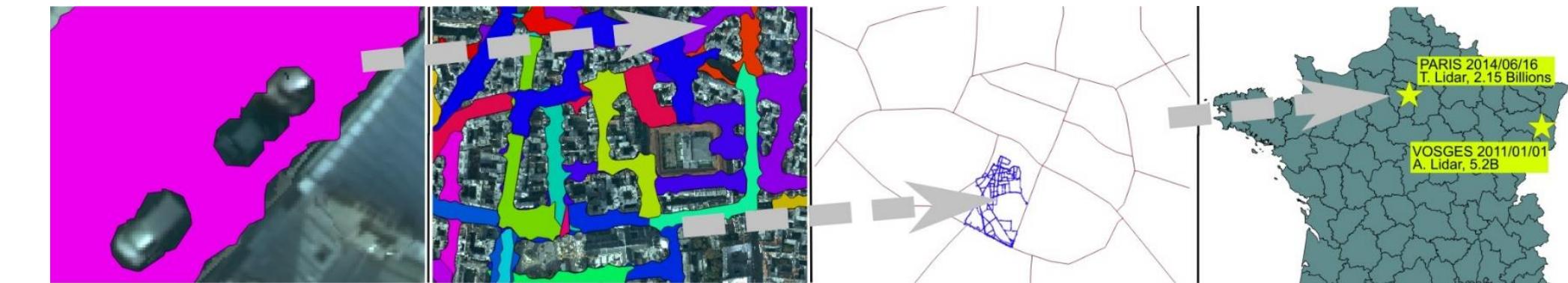
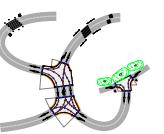
Streets

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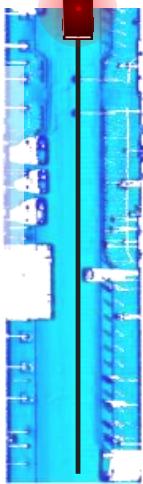
Conclusion



Point Cloud Server: filtering



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With so much data:

- Essential to access only a part of it : example

Patches that are

- far from buildings
- close to the intersection these 2 streets
- aerial view color ≈ pedestrian crossing
- close trajectory
- with high point density



Point Cloud Server: filtering



- Result : finding millions of points amongst billions :
100 ms if indexed !

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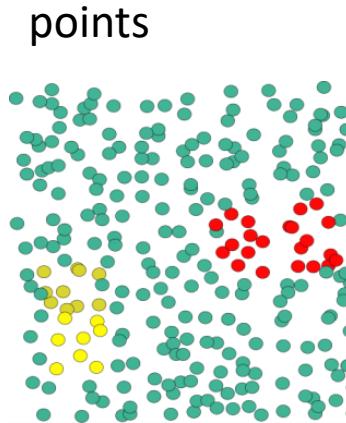
Streets

Interaction

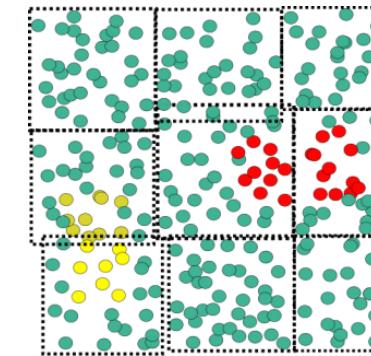
Automation

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Conclusion



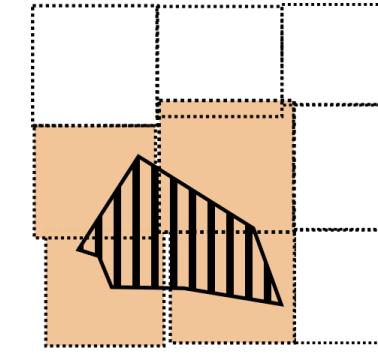
Points in patch



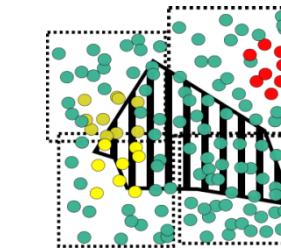
Which points
are inside the
polygon?



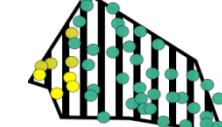
Which **patchs**
are inside the
polygon?



Get points in
these patches



Which
points are
inside the
polygon?



Point Cloud Server: processing



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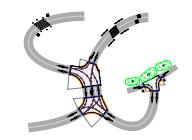
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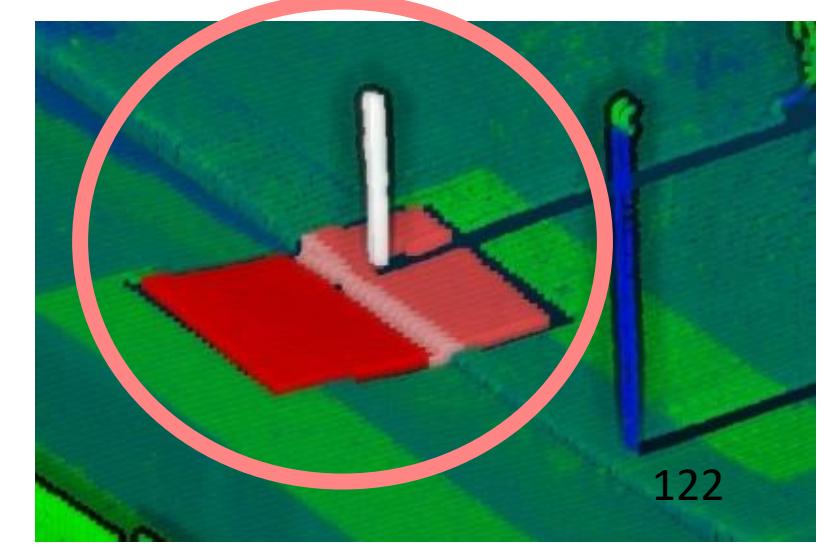
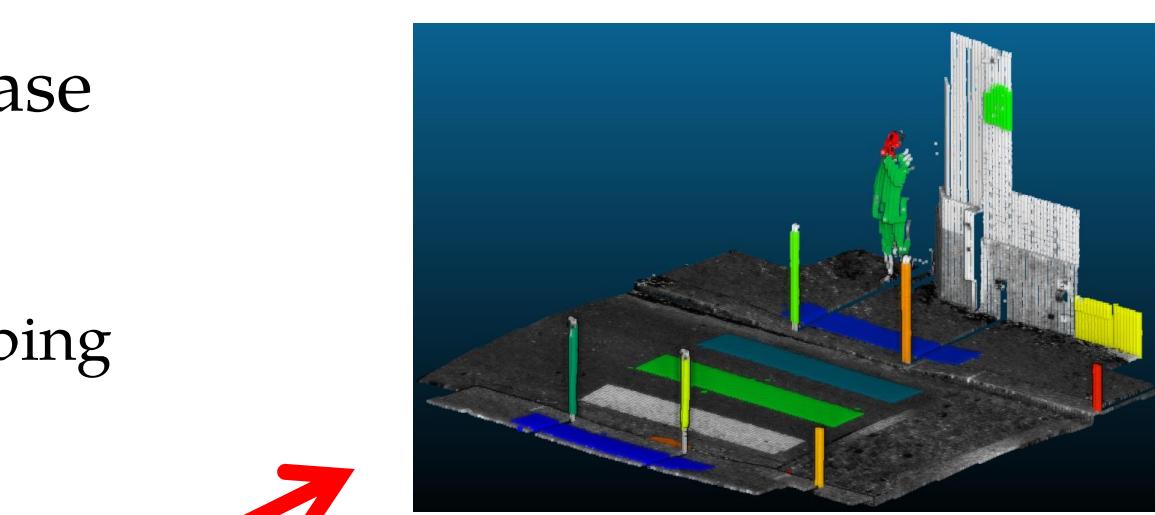
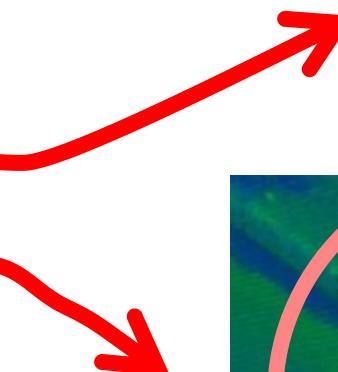
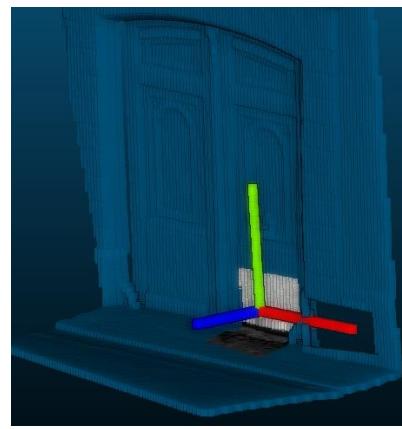


- Postgresql: easy to add in-base processing

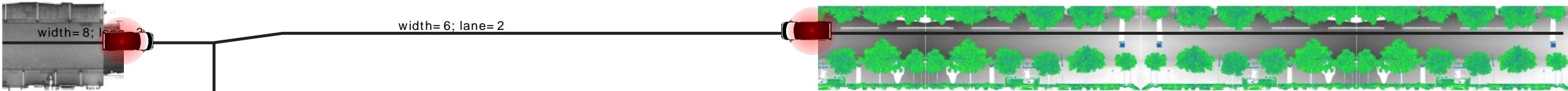
- C/Cpp → for performance
 - R/Python → for fast prototyping

- Example :

- Verticality descriptor
 - Unsupervised clustering
 - Plane & cylinder detection



Point Cloud Server: processing



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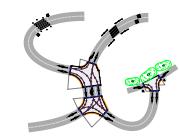
Streets

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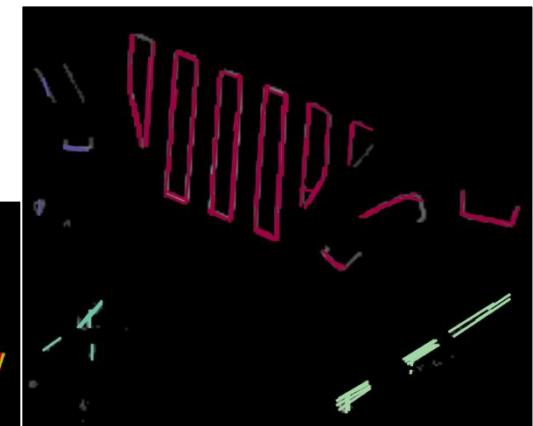
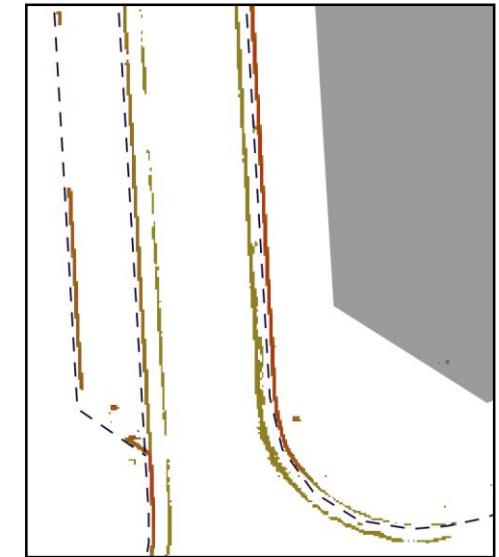
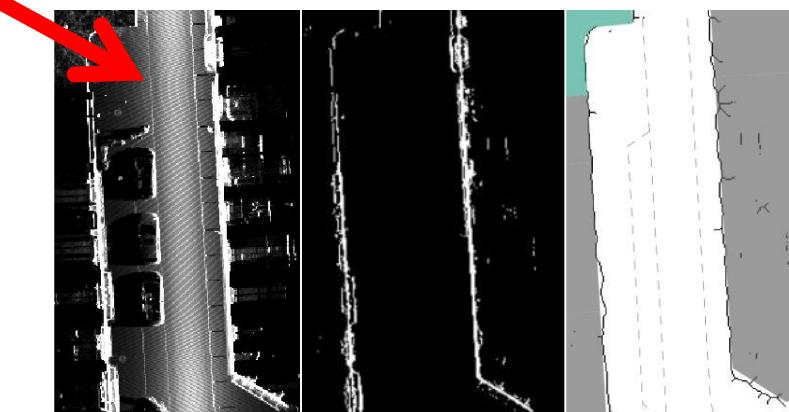
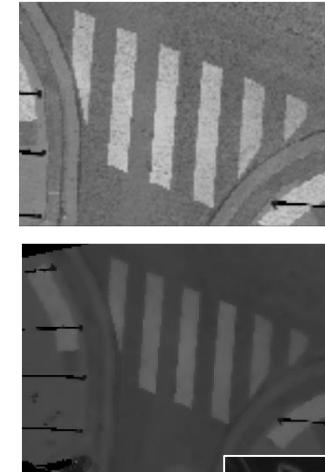
Automation

P.C. Server

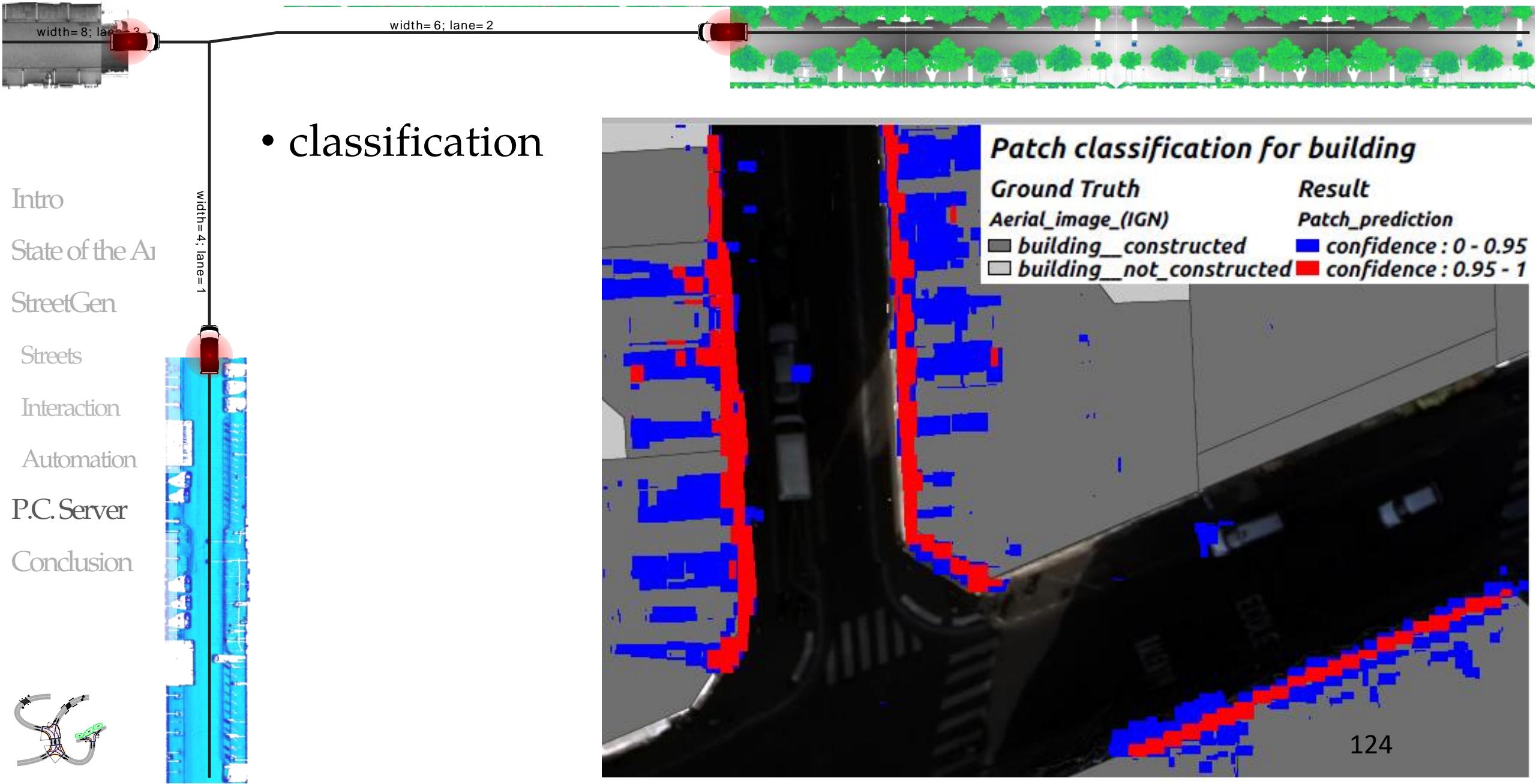
Conclusion



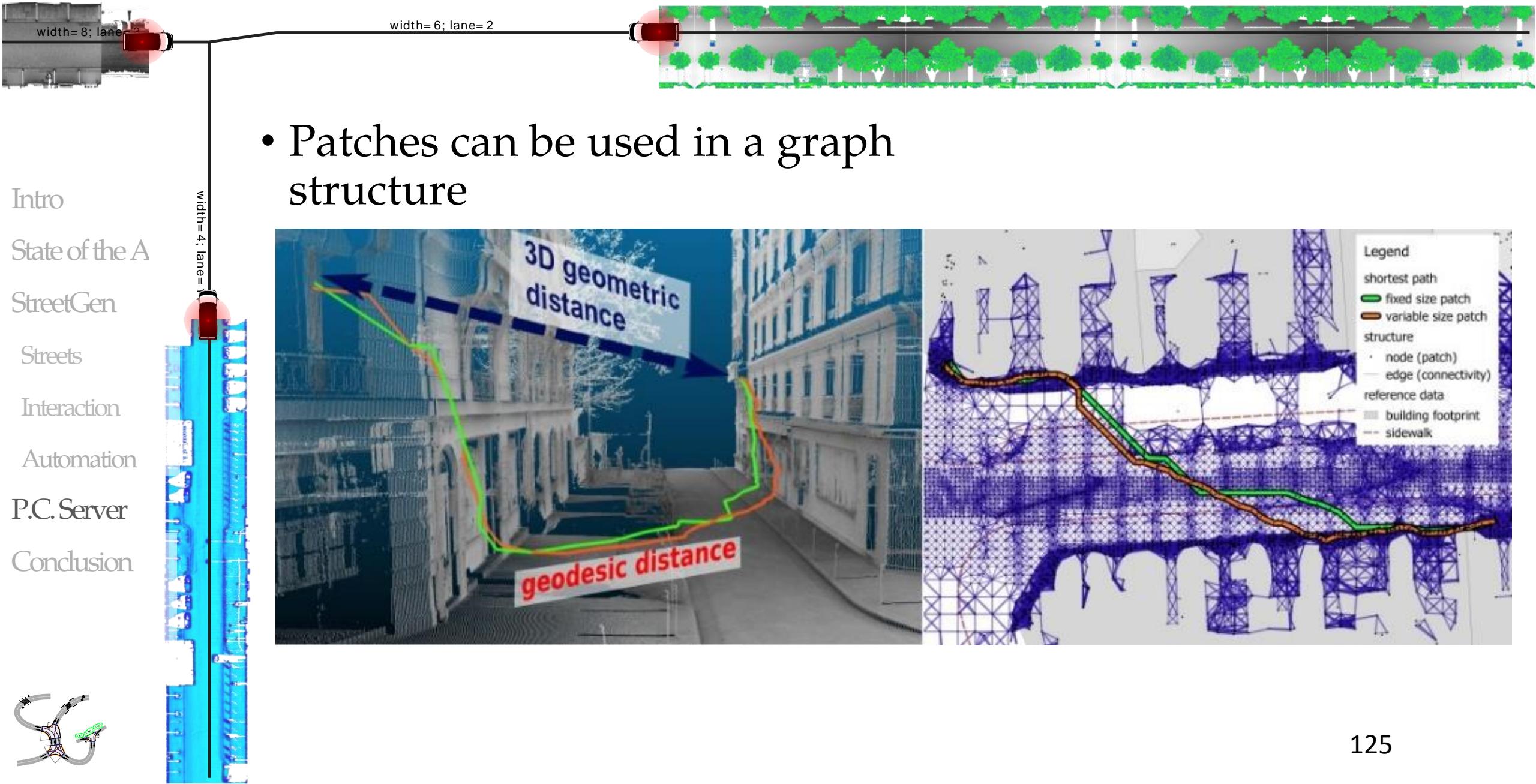
- Converting patch to raster
 - Cornerstone detection
 - Marking detection
 - Façade detection



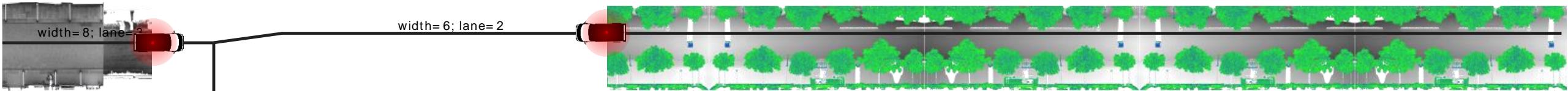
Point Cloud Server: processing



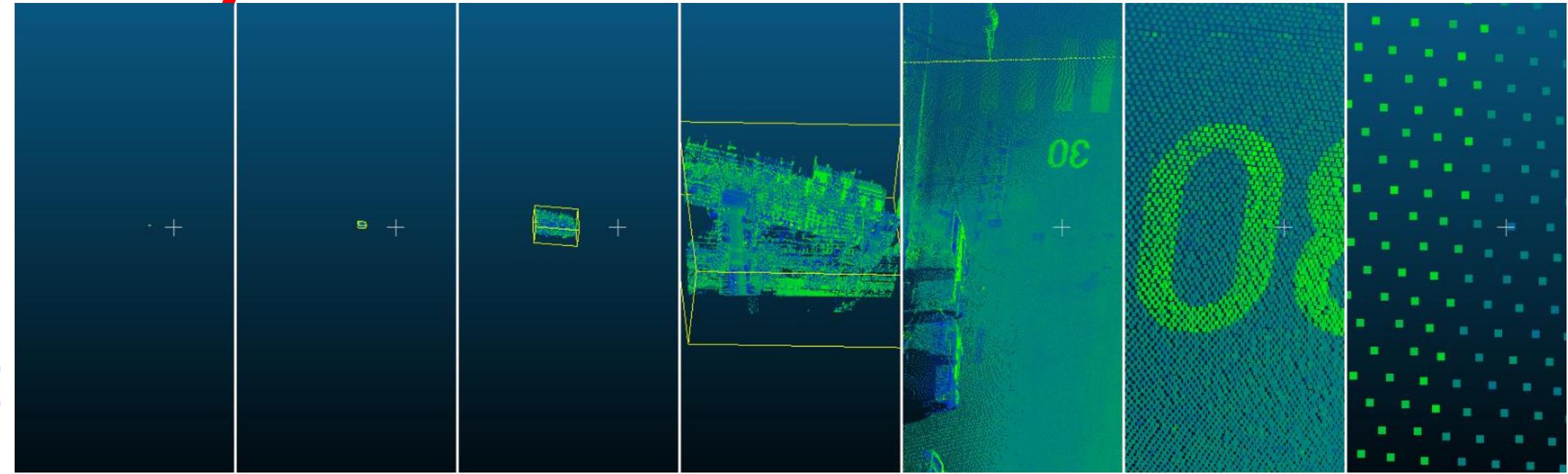
Point Cloud Server: processing



Point Cloud Server: Level Of Detail

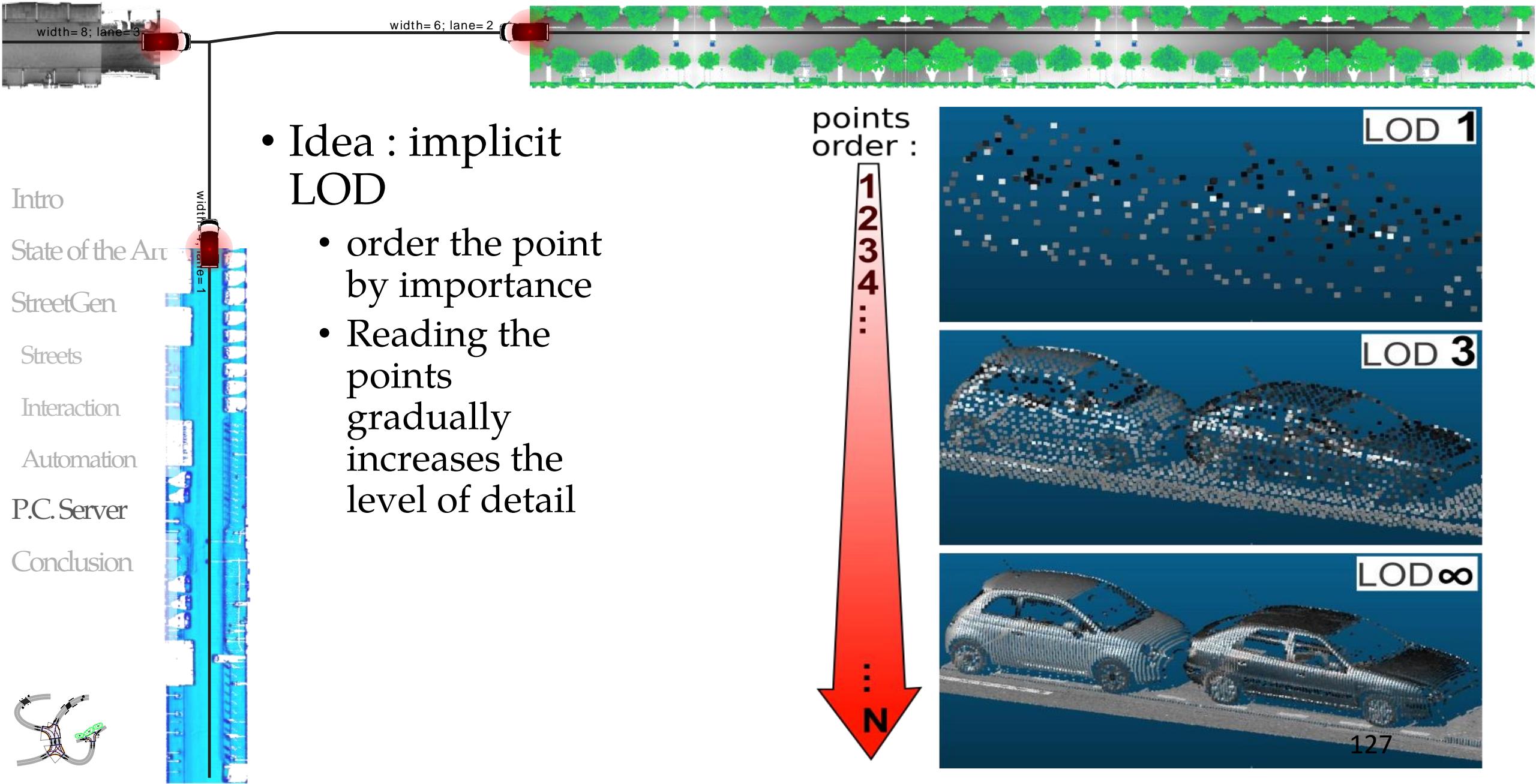


- Level Of Detail (LOD):
 - Sometimes you don't need all the points
12 Millions points, really?



User needs only a given Level Of Detail.

Point Cloud Server: Level Of Detail



width=8; lane=3

width=6; lane=2

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width=1; lane=1

points order :
1
2
3
4
⋮
N

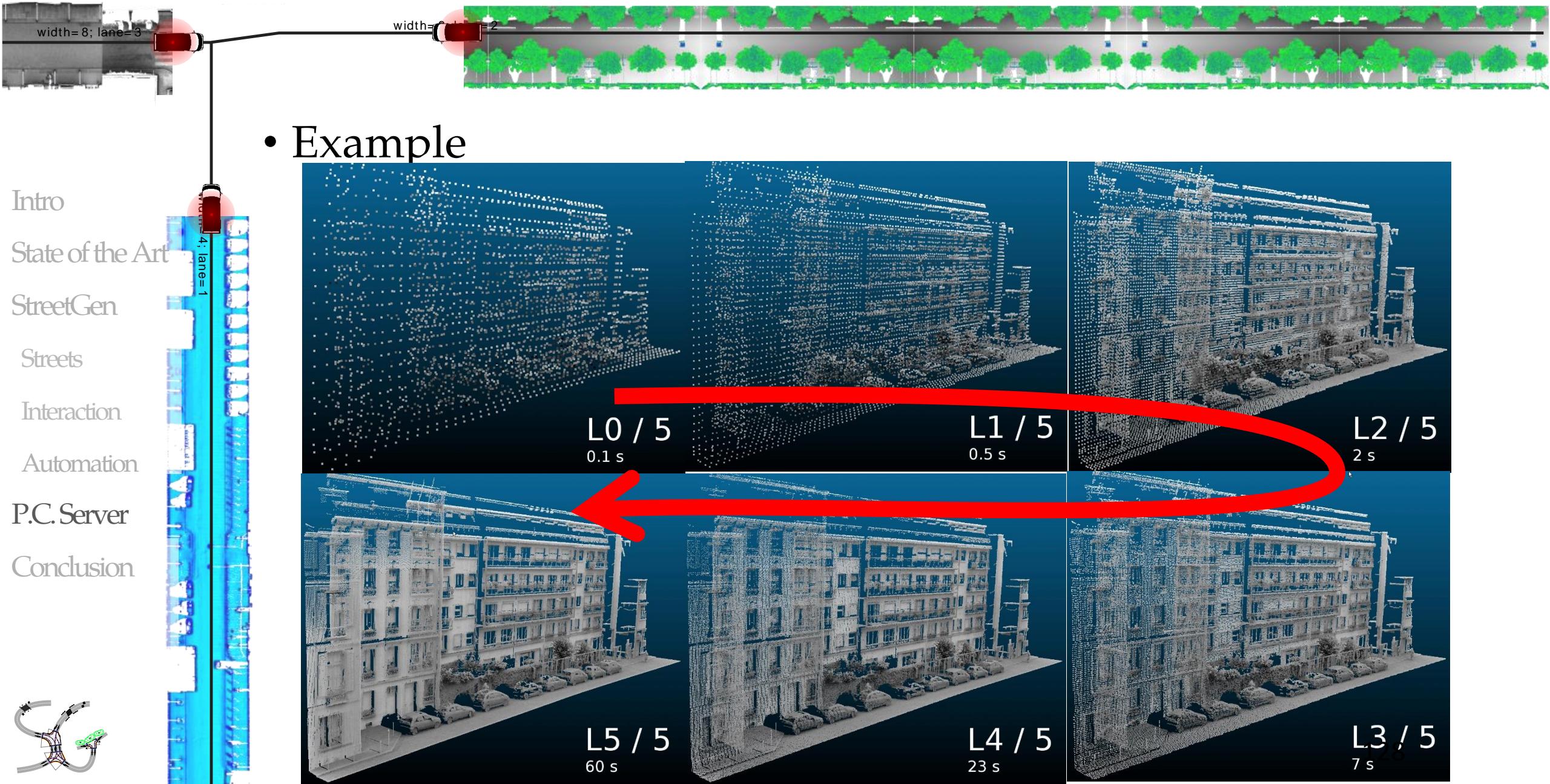
LOD 1

LOD 3

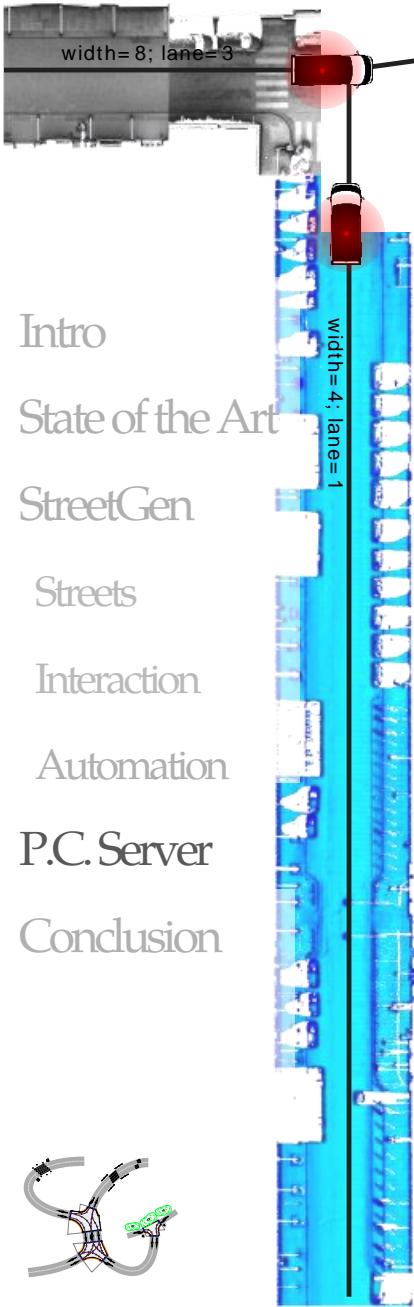
LOD ∞

127

Point Cloud Server: Level Of Detail

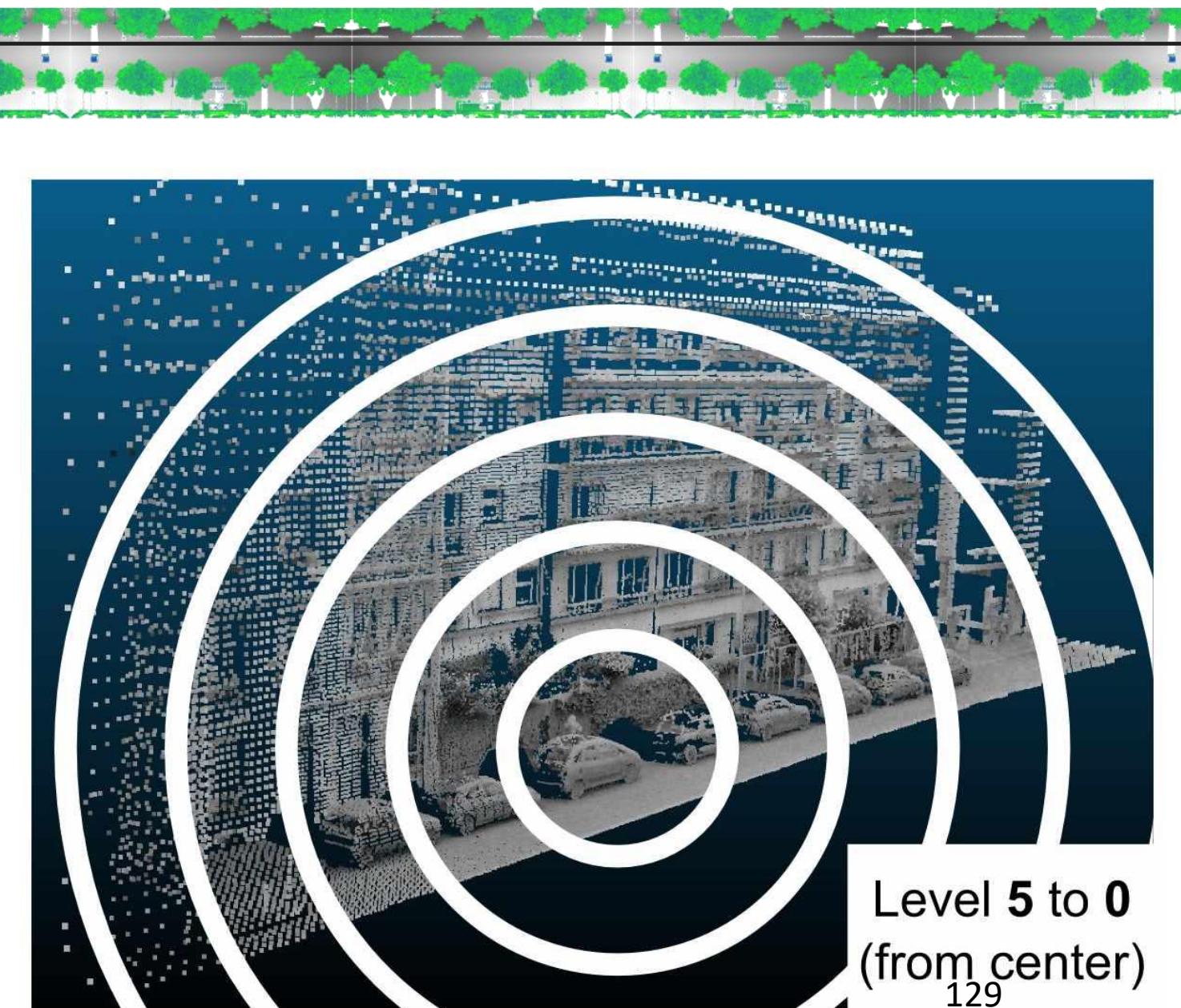


Point Cloud Server: Level Of Detail



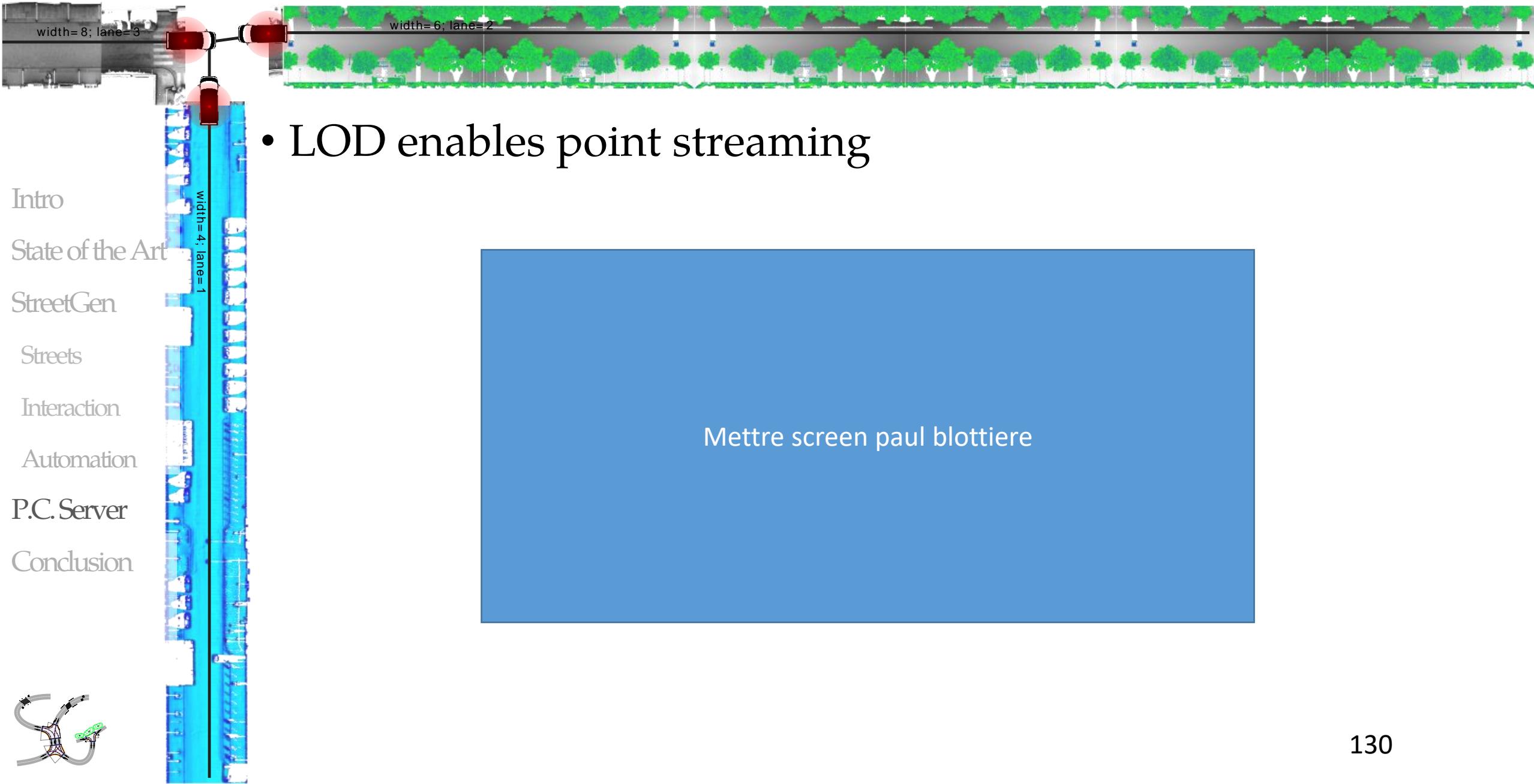
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- For visualization, LOD depends on distance to camera



Level 5 to 0
(from center)
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Point Cloud Server: Level Of Detail



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Point Cloud Server: Level Of Detail

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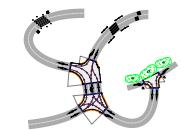
Streets

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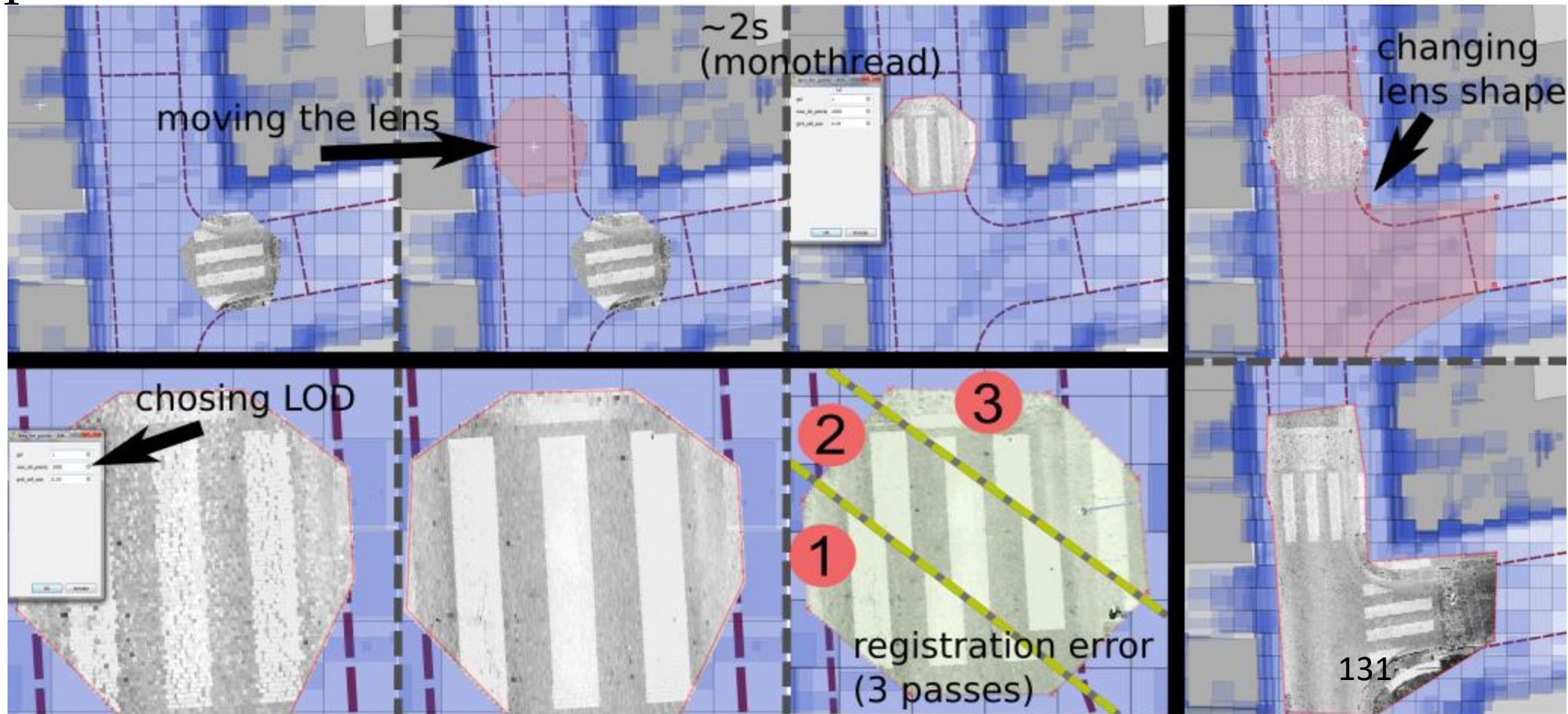
Automation

P.C. Server

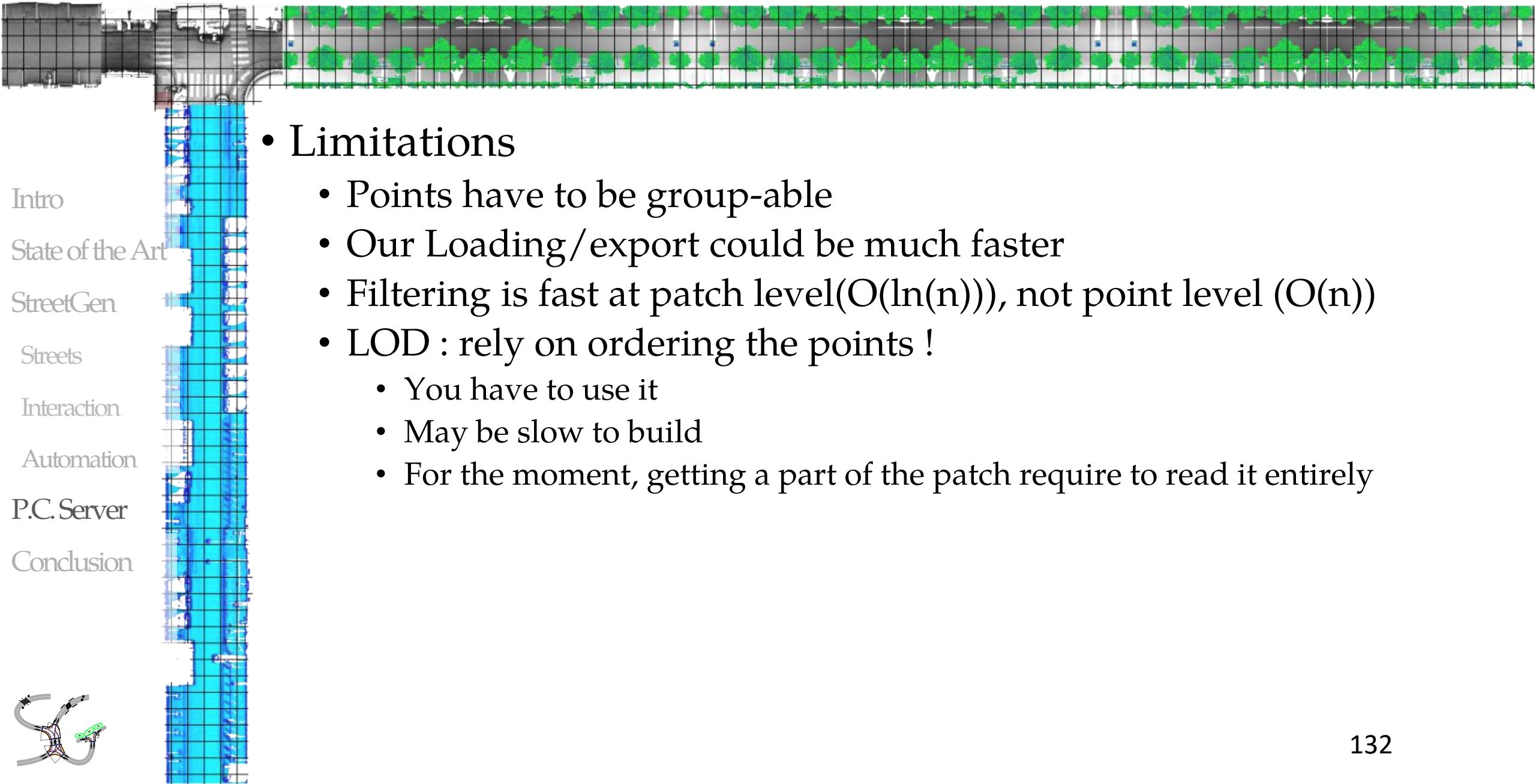
Conclusion



- Also for classical GIS soft that can't deal with too many points



Point Cloud Server: Level Of Detail



- Limitations

- Points have to be group-able
- Our Loading/export could be much faster
- Filtering is fast at patch level($O(\ln(n))$), not point level ($O(n)$)
- LOD : rely on ordering the points !
 - You have to use it
 - May be slow to build
 - For the moment, getting a part of the patch require to read it entirely

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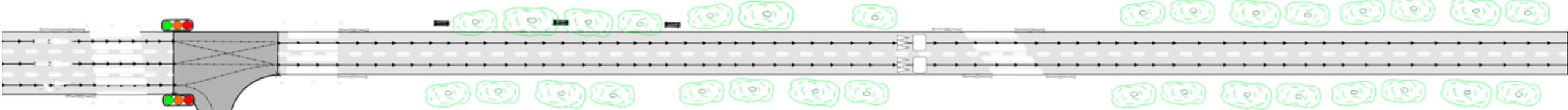
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Perspectives

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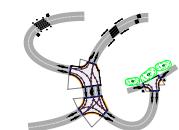
Streets

Interaction

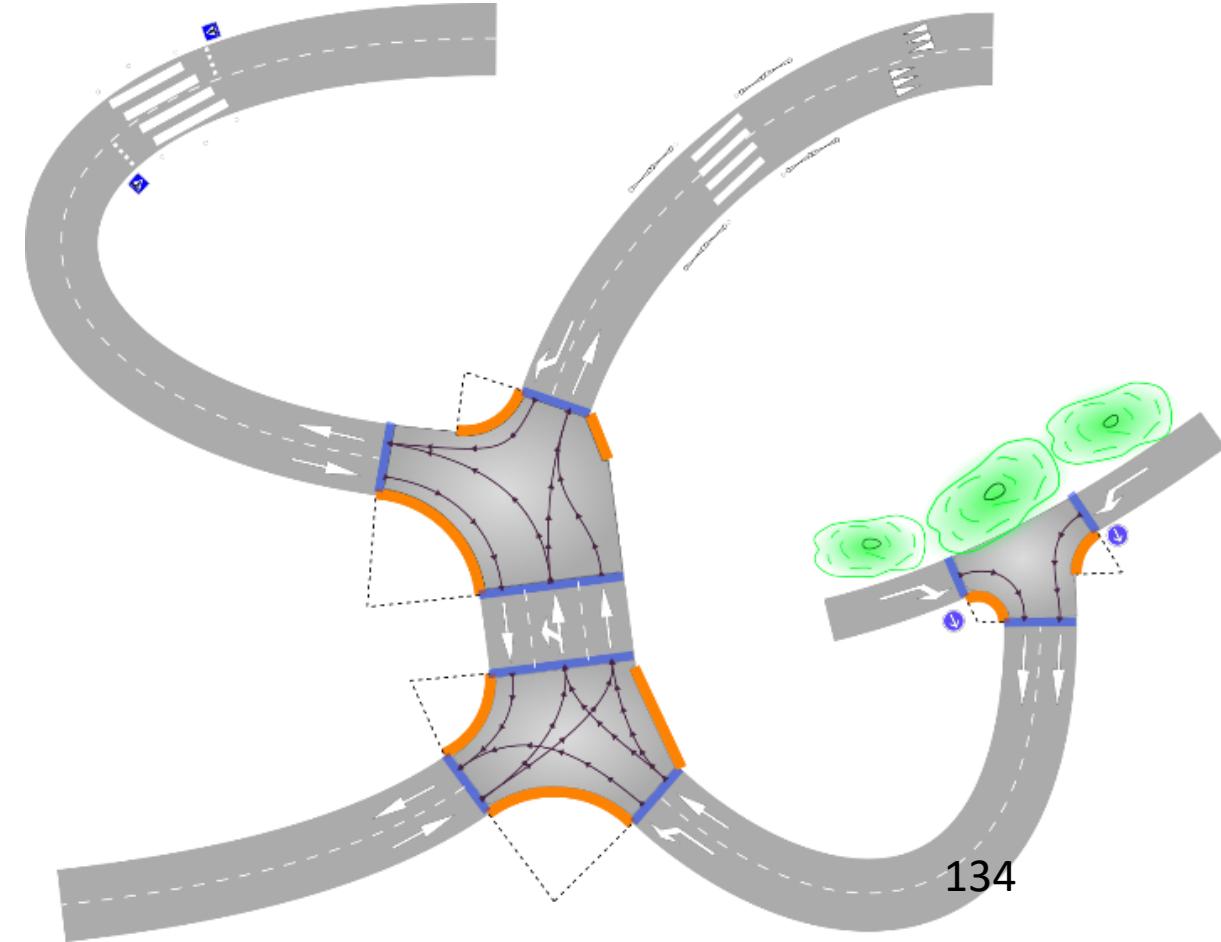
Automation

P.C. Server

Conclusion



- From low information: generate best guess street model at Paris scale and edit it (multi-user, using many GIS software): StreetGen



Conclusion: Summary

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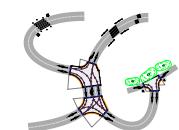
Streets

Interaction

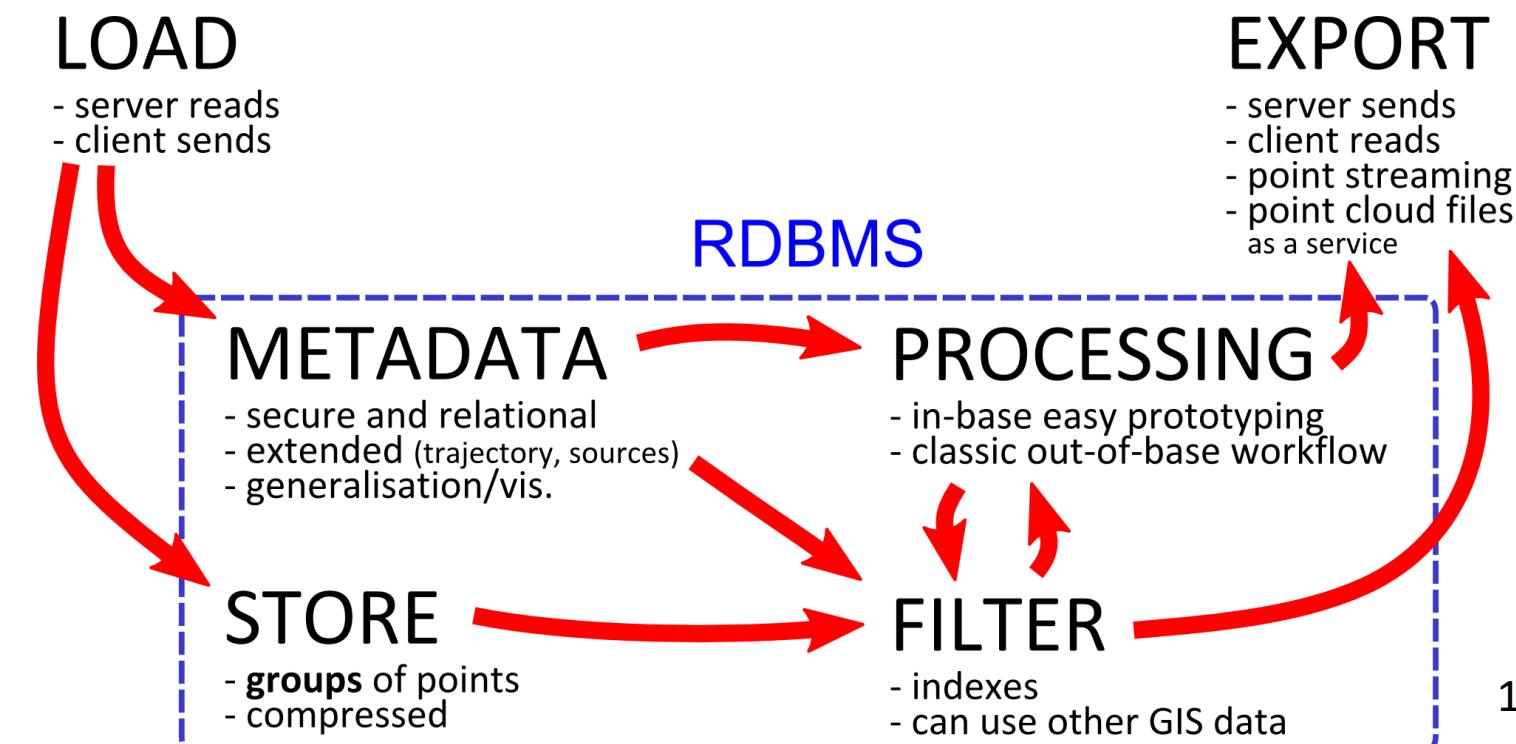
Automation

P.C. Server

Conclusion



- Manage a massive amount of 3D points (from mobile mapping). Act as a service for usage/processing/visu:
Point Cloud Server



Conclusion: Summary

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State of the Art

StreetGen

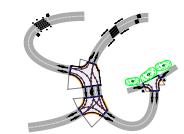
Streets

Interaction

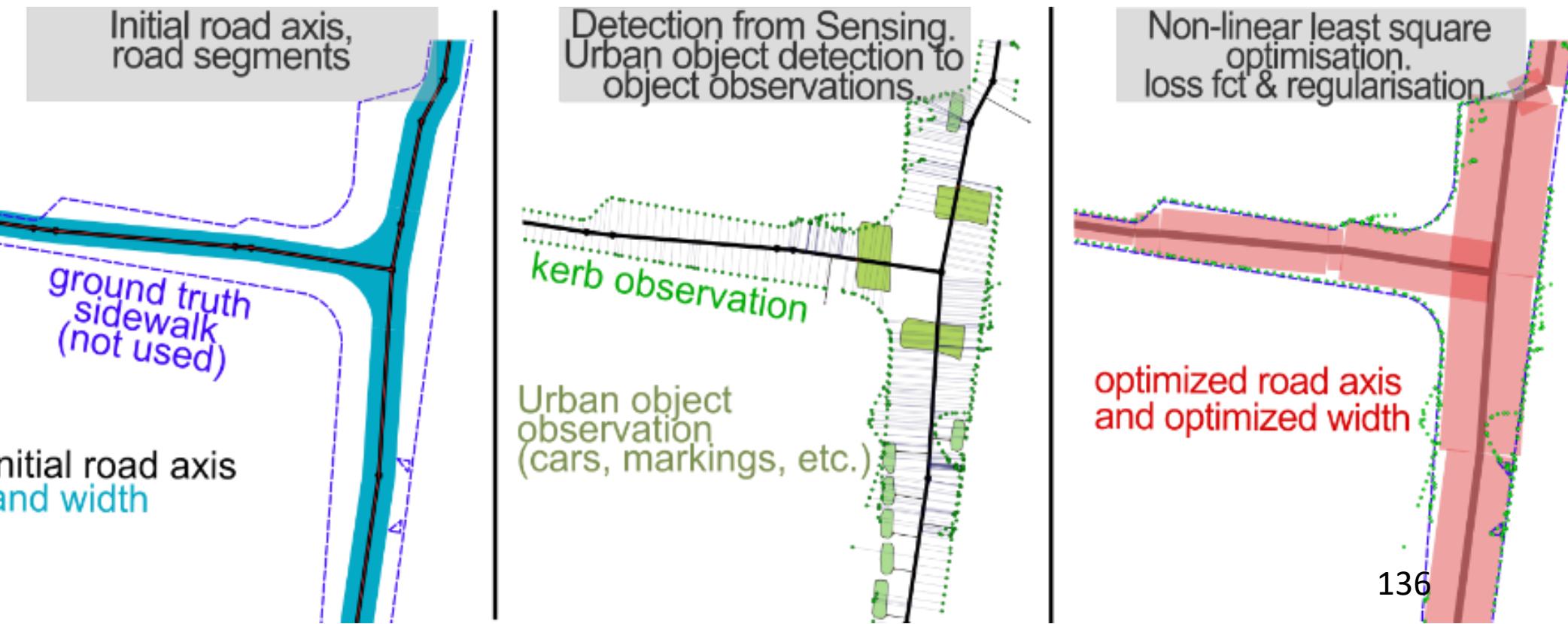
Automation

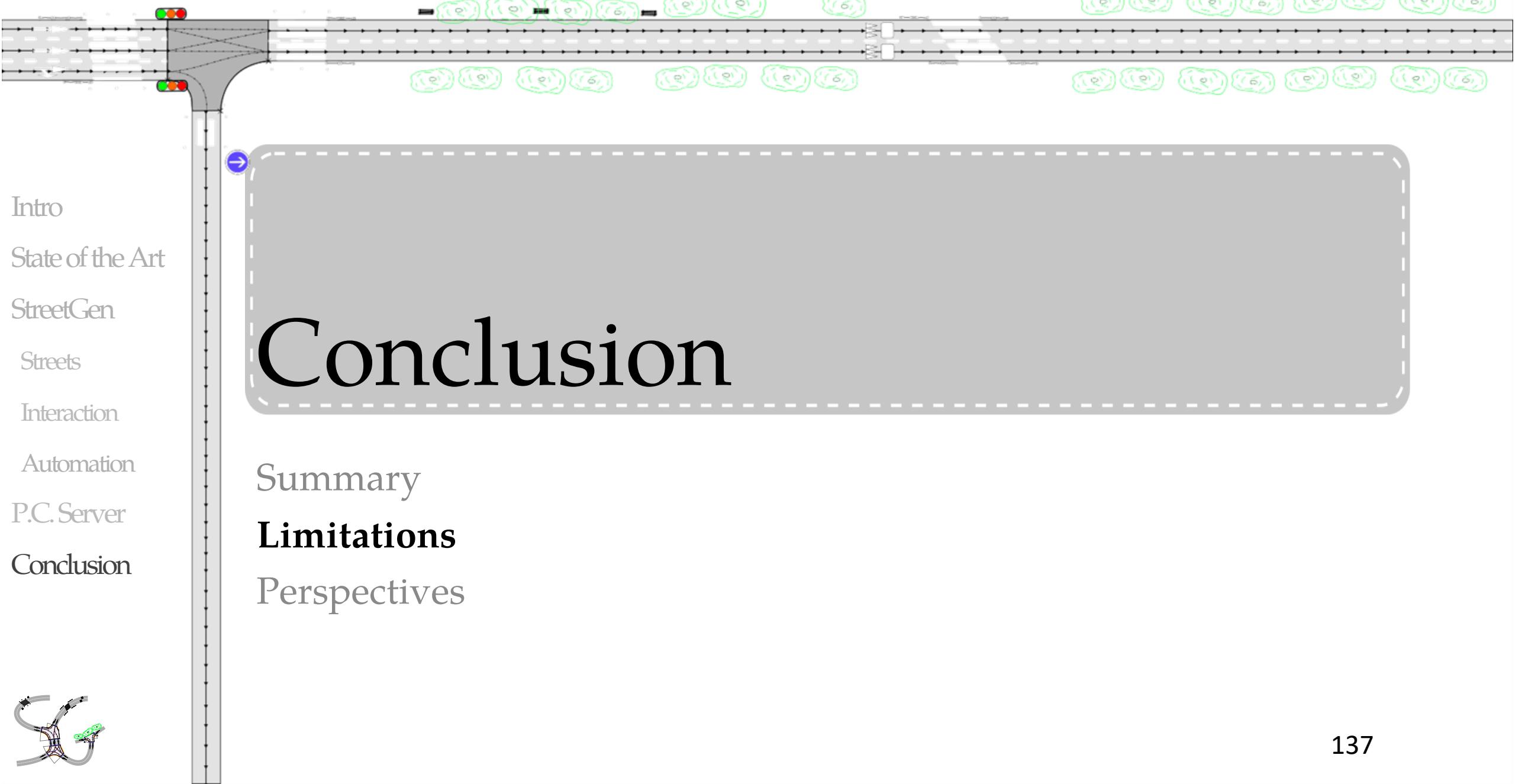
P.C. Server

Conclusion



- Perform inverse procedural modelling by fitting a road model to various observations





Conclusion

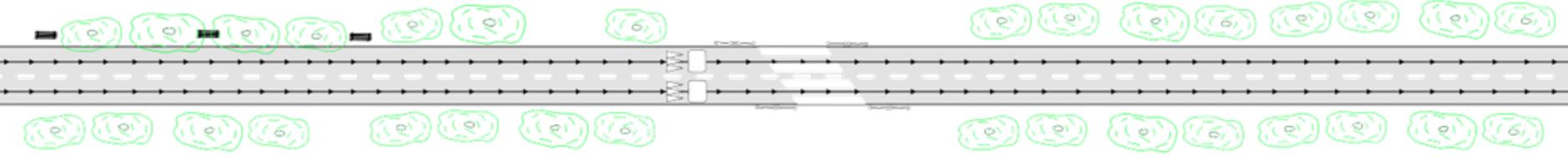
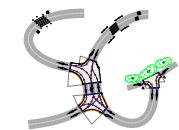
Summary

Limitations

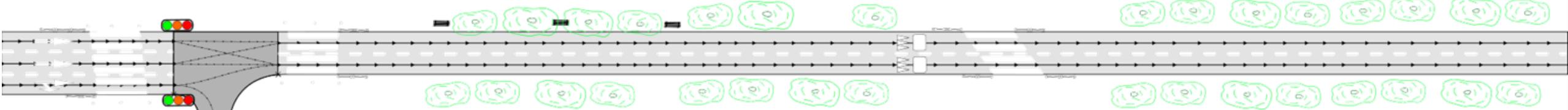
Perspectives

Conclusion: Limitations

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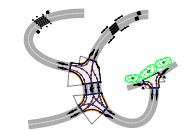
- Very simple street model: revolves around street axis.
 - Too simple?
 - Pedestrian street?
 - Based on topology → hard to maintain/scale/edit
- Point Cloud Server :
 - Need several processing methods to extract observations
 - Coupling with street images missing
 - 3D from images? Updating?
- Objects are created/edited manually by user
 - Tedious, not much sense



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Conclusion: Perspectives

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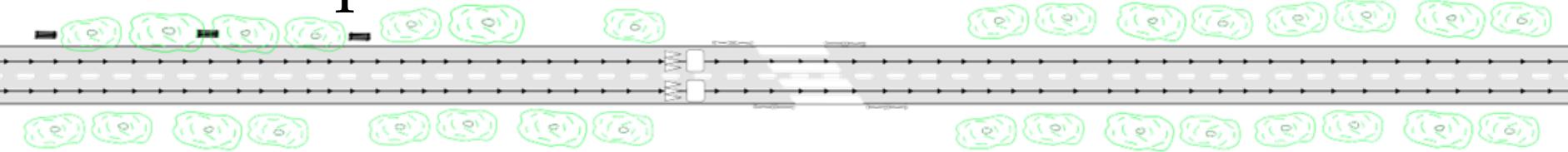
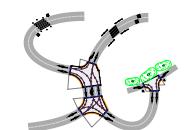
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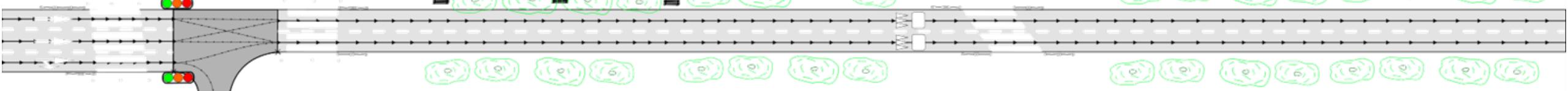
P.C. Server

Conclusion



- Only the beginning of inverse procedural street modelling.
 - Dealing with objects and road model simultaneously calls for much stronger modelling and optimisation methods
 - Object should be created by template/ pattern/ grammar/procedural functions!
 - Optimisation should be more powerfull (RJ-MCMC)

Conclusion: Perspectives



- Since the beginning of the thesis :
 - Major trend in smart vehicle/autonomous cars
 - → maps no more required only by traditional data provider
 - → maps potentially required by every (Billion) cars
- Many methods on low level classification
 - Different cars with different hard → need a more abstract street model

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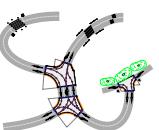
Streets

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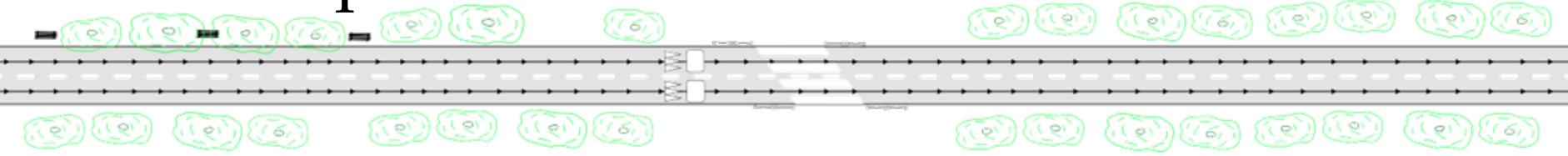
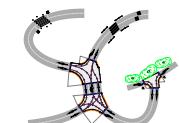
P.C. Server

Conclusion



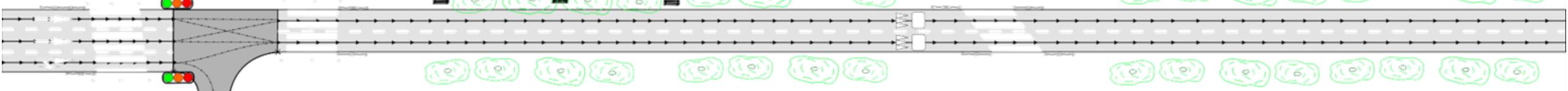
Conclusion: Perspectives

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- “smart city” is trending
 - There is several cities in one city:
 - Saint Mandé entry roundabout .
 - Day : next to Lenotre: luxury caterer
 - Night: hookers
 - Time is essential (simulation/understanding)
 - 4D street modelling ? (garbage/ café terrace/ parking behaviour)

Conclusion: Perspectives



- Understanding city may be key to planning
- To understand → study city history

- Historical geodata
 - Hand drawn maps
 - Information needs to be extracted

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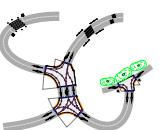
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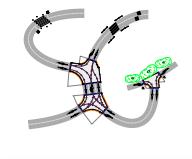
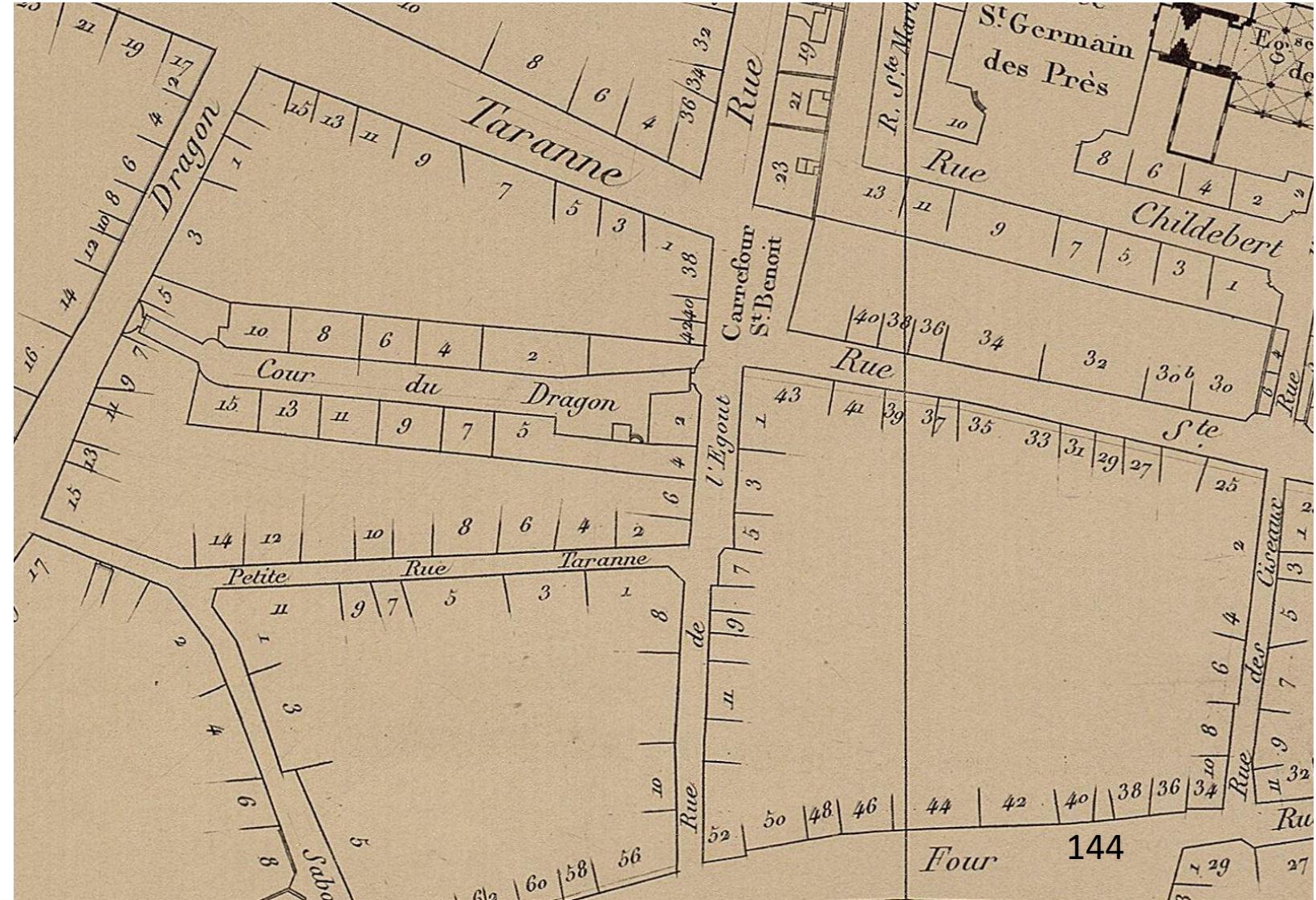
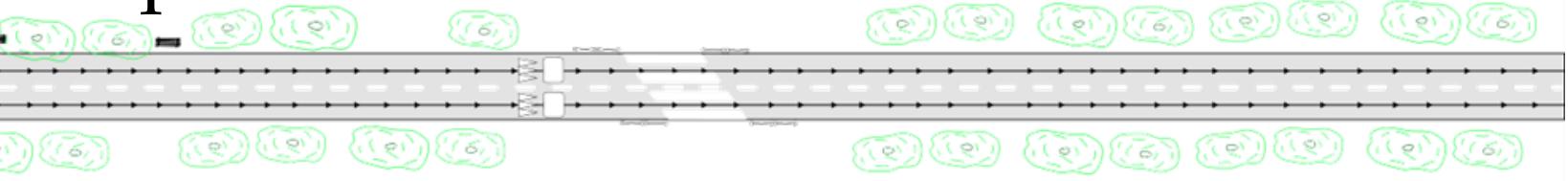
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Conclusion: Perspectives

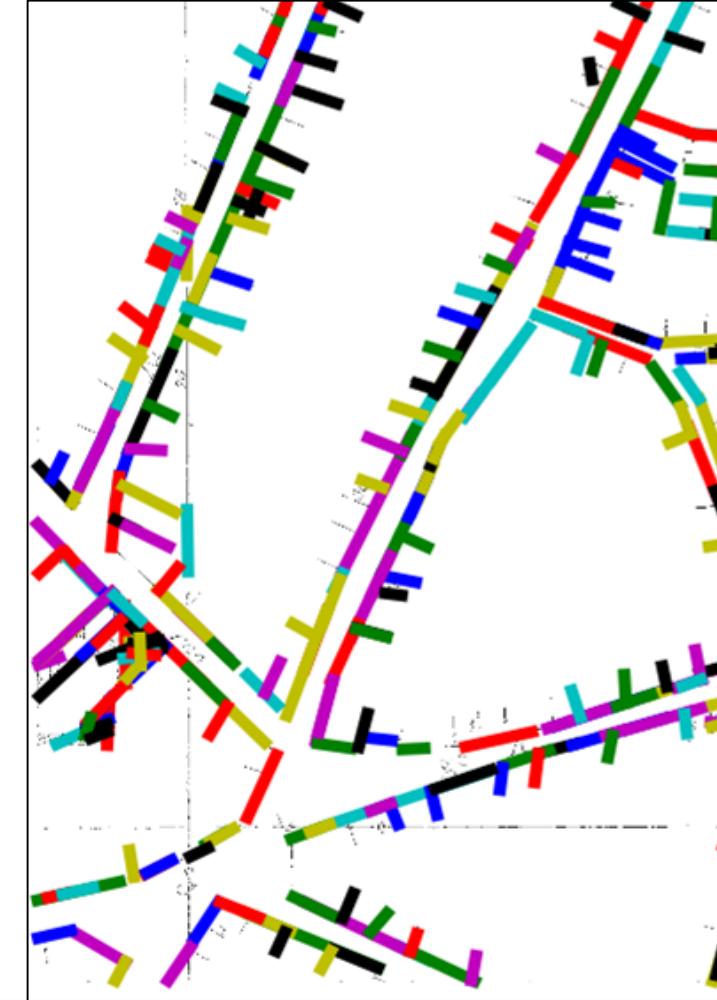
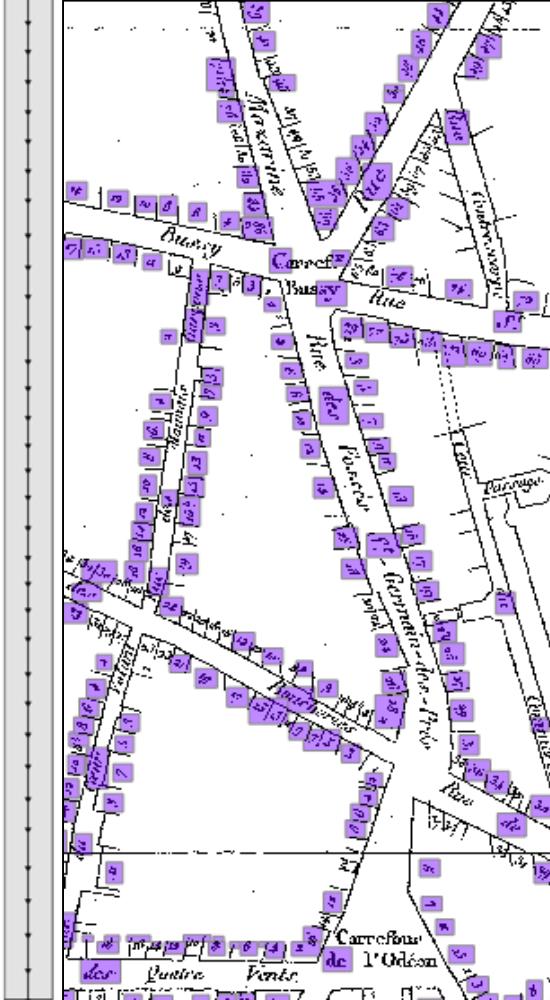
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- Jacoubet,
1810-1836 :
- road model
with
optimisation
& Streetgen
?



Conclusion: Perspectives

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- Extract building number, buildings limits, street surface (B. Vallet)

Conclusion: Perspectives

- Turgot, 1734-1739 : isometric persp.

procedural modelling candidate?



QUESTIONS

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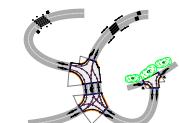
Streets

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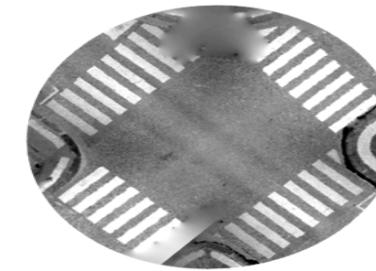
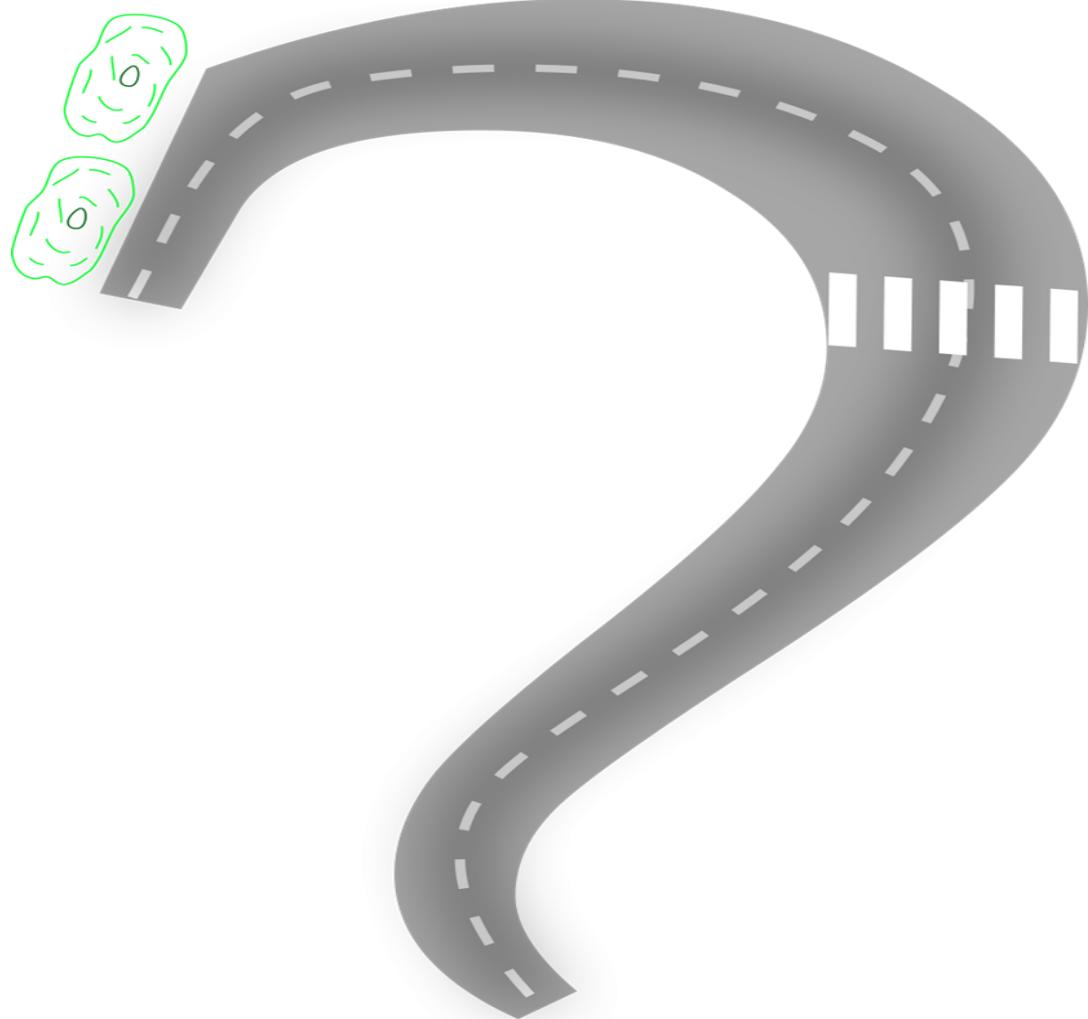
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- Thanks
- Questions?



TODO

- Conclusion need illustrations and splitting slides
- Solve the todo

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notes

- Premiere page: logos en gros
- Intro : trop fouilli, trop long
- Point cloud server : mettre après optim
- ...

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