

Inverse procedural Street Modelling: from interactive to automatic reconstruction

Phd Defense : Rémi Cura, 2016/09/12

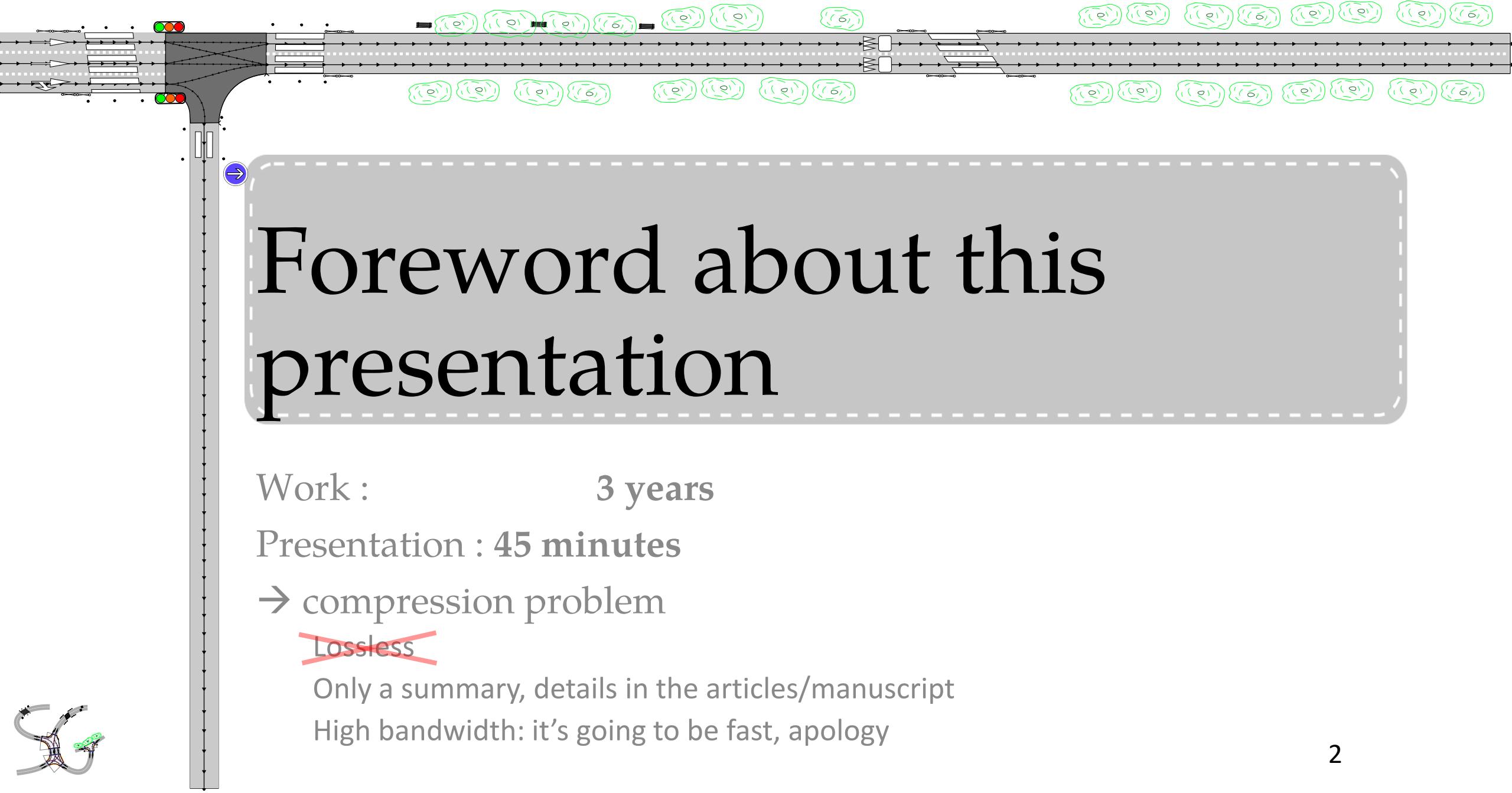
*Université Paris-Est
École Doctorale Mathématiques et Sciences et Technologies
de l'Information et de la Communication (MSTIC)*

Jury:

Pr. Christian Heipke (IPI) **R**
Pr. Peter Van Oosterom (TUDelft) **R**
Dr. Florent Lafarge (INRIA) **E**
Pr. Gilles Gesquière (LIRIS) **E**

Dr. Julien Perret (IGN) **S**
Dr. Nicolas Paparoditis (IGN) **D**
Dr. Kevin Lyvan (Thales) **S**





Foreword about this presentation

Work : **3 years**

Presentation : **45 minutes**

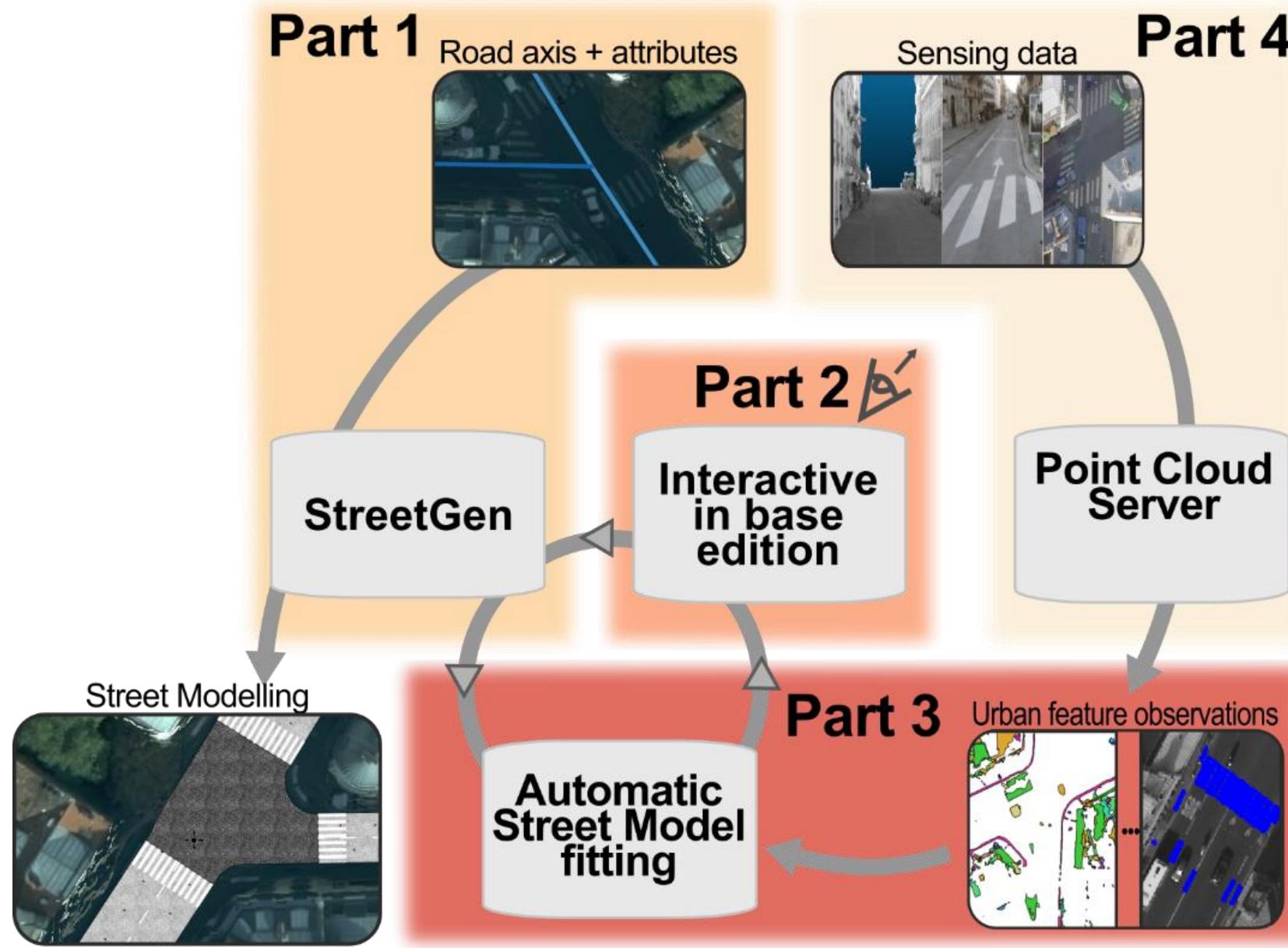
→ compression problem

~~Lossless~~

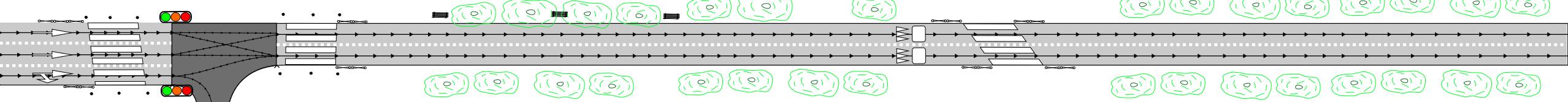
Only a summary, details in the articles/manuscript

High bandwidth: it's going to be fast, apology

Abstract



PLAN



Intro

State of the Art

StreetGen

Streets

Interaction

Automation

P.C. Server

Conclusion



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

width= 8; lane= 3

width= 6; lane= 2

Intro

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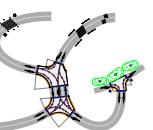
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Introduction

Why model streets?

Usages for street model

Introduction: Streets are important

width= 8; lane= 3

width= 6; lane= 2

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- 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

im

im

Introduction: having a model is important

width= 8; lane= 3

width= 6; lane= 2

- 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

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width= 4; lane= 1

width= 8; lane= 3

width= 6; lane= 2

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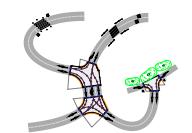
Conclusion

width= 4; lane= 1

Introduction

Why model streets?

Usages for street model



Introduction: usages for street model

width= 8; lane= 3

width= 6; lane= 2

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

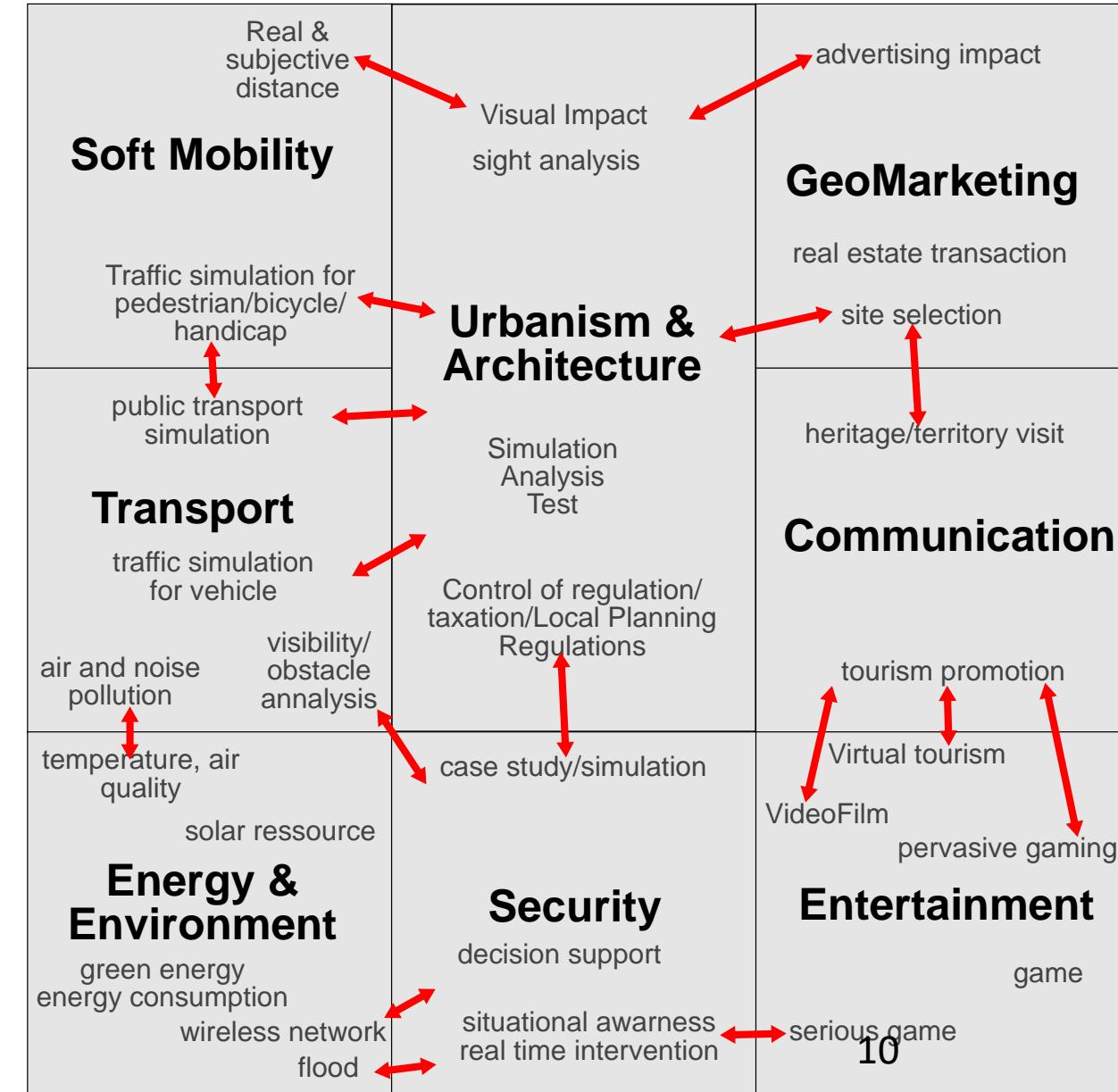
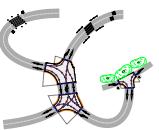
im

im

Introduction: usages for city model

- width=8; lane=3
- width=6; lane=2
- Street model ⊂ city model
- Many usages for a city model
 - Urbanism
 - Transport
 - Environment
 - Security
 - Communication
 - ...

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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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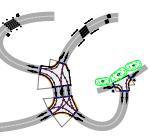
P.C. Server

Conclusion

State of the art

Modelling street, why is it hard?

Existing methods



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

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

im

im

State of the art: modelling street is hard

edge_id= 15; next_l= 16
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- complex / traffic / organisation/ sensing

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edge_id= 17; next_l= 16
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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
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- complex / traffic / organisation/ sensing

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



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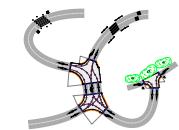
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- complex / traffic / organisation/ sensing

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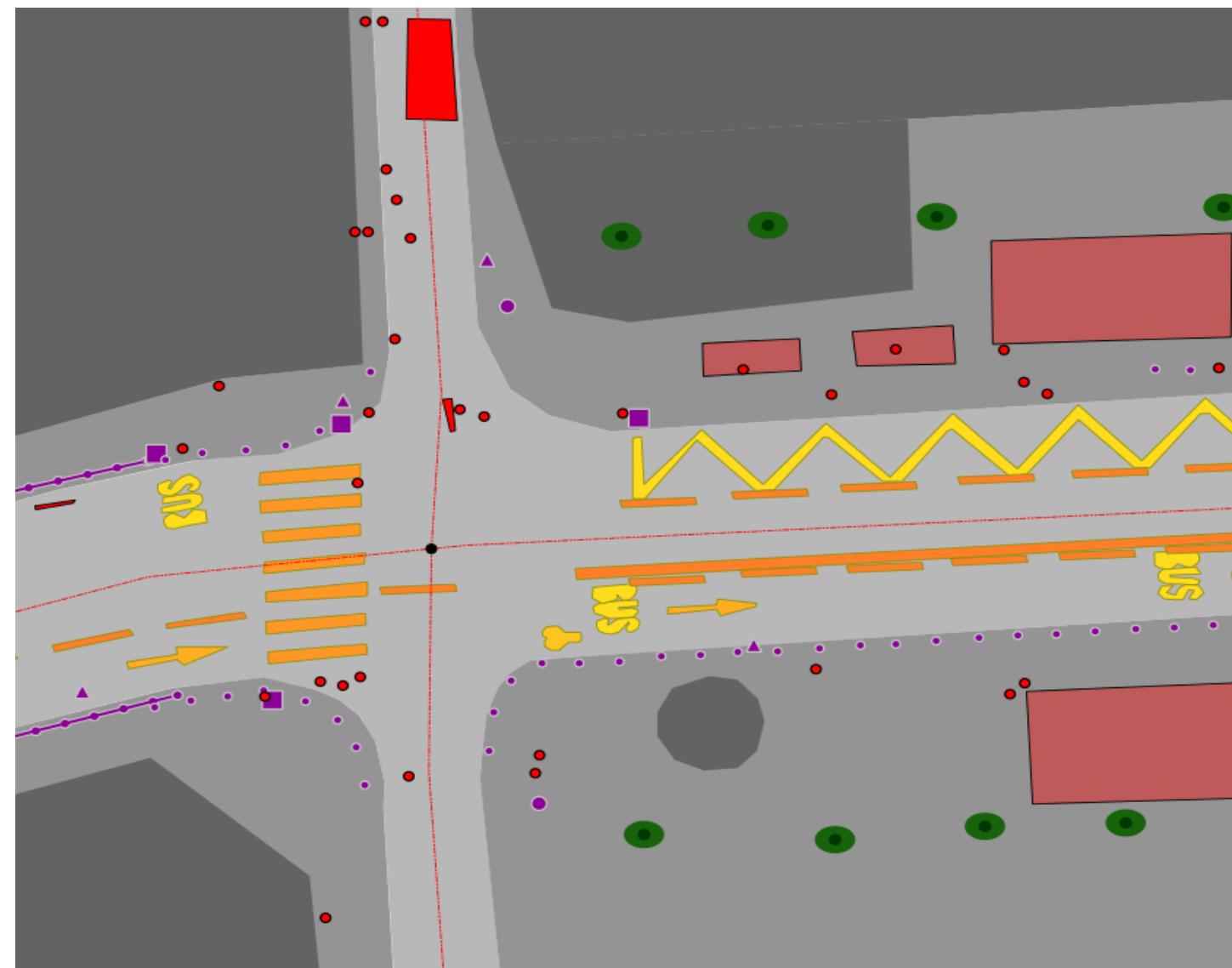
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edge_id= 17; next_l= 16



road_network

intersection node
road axe

vegetation

tree

mobility

pedestrian
bicycle
vehicle
bus_stop
metro
bus
metro

Signage

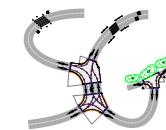
bu
ve
fl
pp
ma

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
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- complex / traffic / organisation/ sensing

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- complex / traffic / organisation/ sensing

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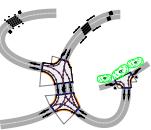
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State of the art: modelling street is hard

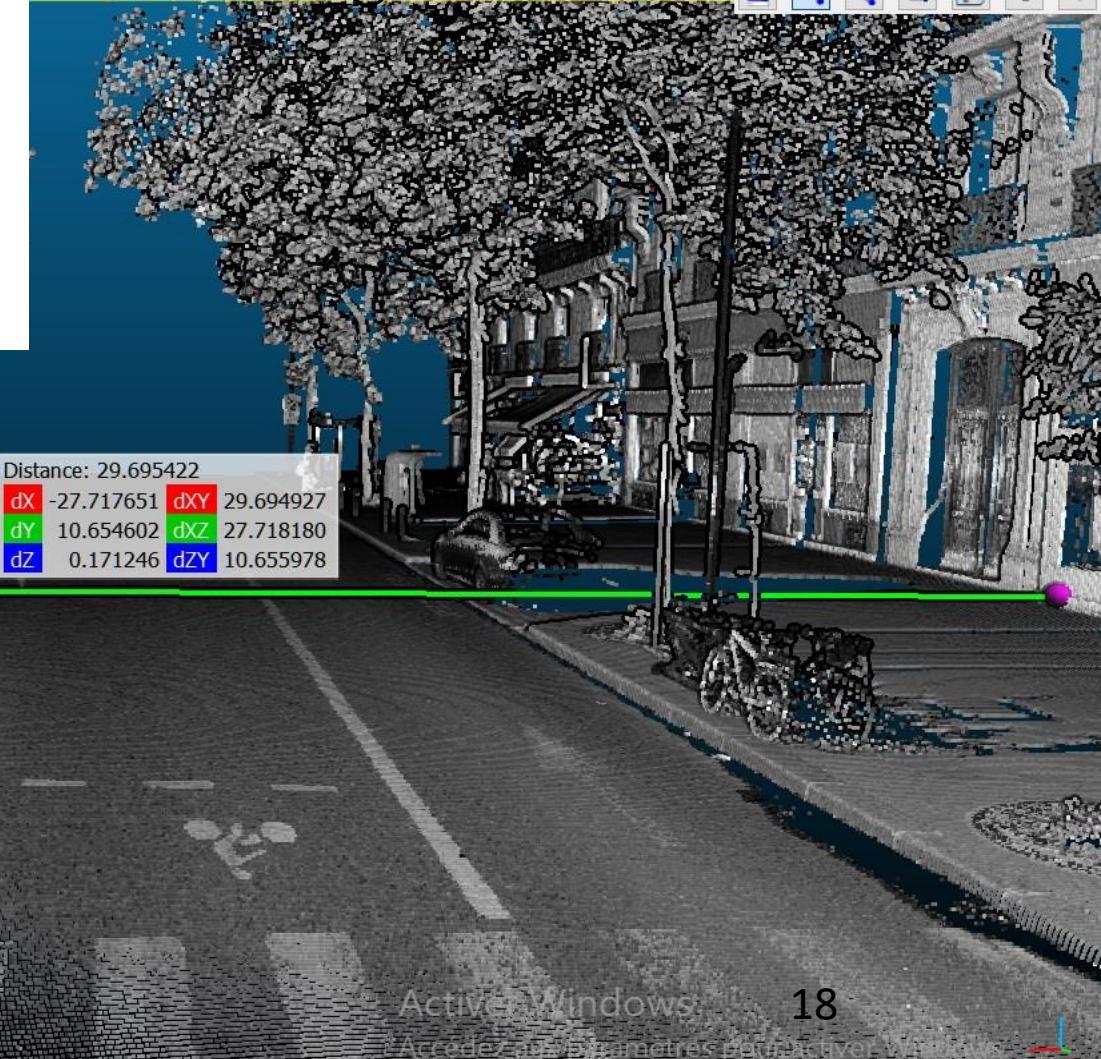
edge_id=15; next_l=16
end_node=3 ...

- complex / traffic / organisation/ sensing

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

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

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



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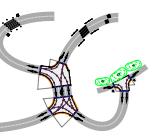
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Modelling street, why is it hard?

Existing methods



State of the art: Existing models

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

edge_id=16; next_l=17
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 ...

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

im

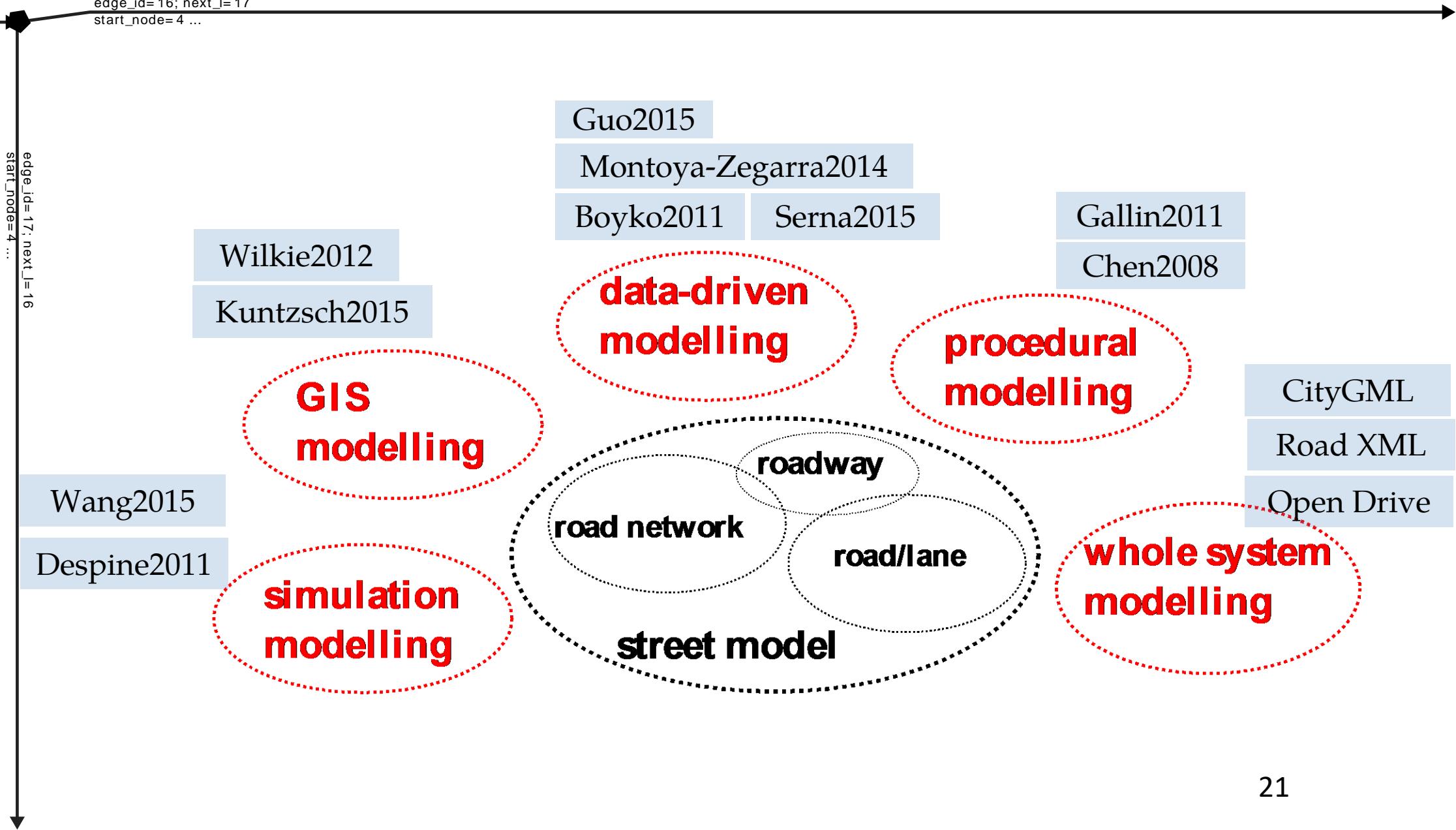
im

State of the art: Existing models

edge_id=15; next_l=16
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State of the art: Existing models

edge_id=15; next_l=16
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System / GIS / Simulation / Procedural / Data-driven

- 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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edge_id=17; next_l=16
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Transportation module

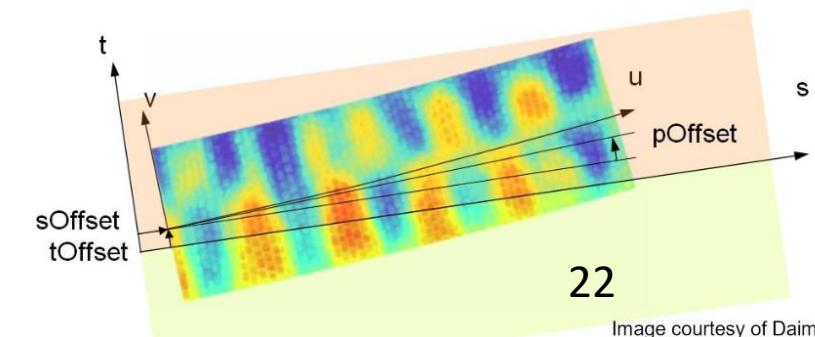
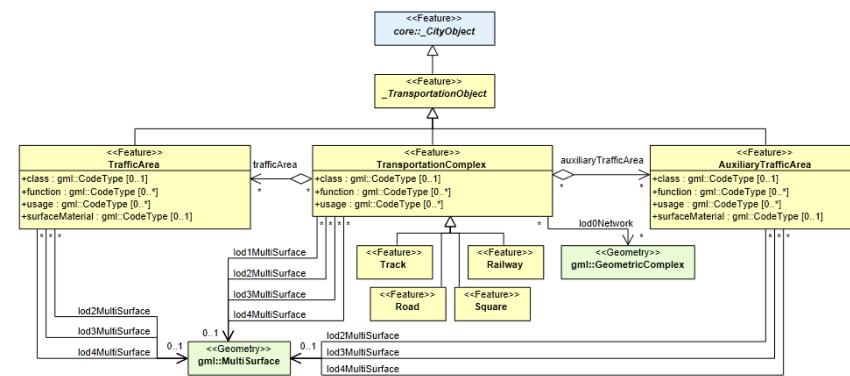


Image courtesy of Daimler AG

State of the art: Existing models

edge_id=15; next_l=16
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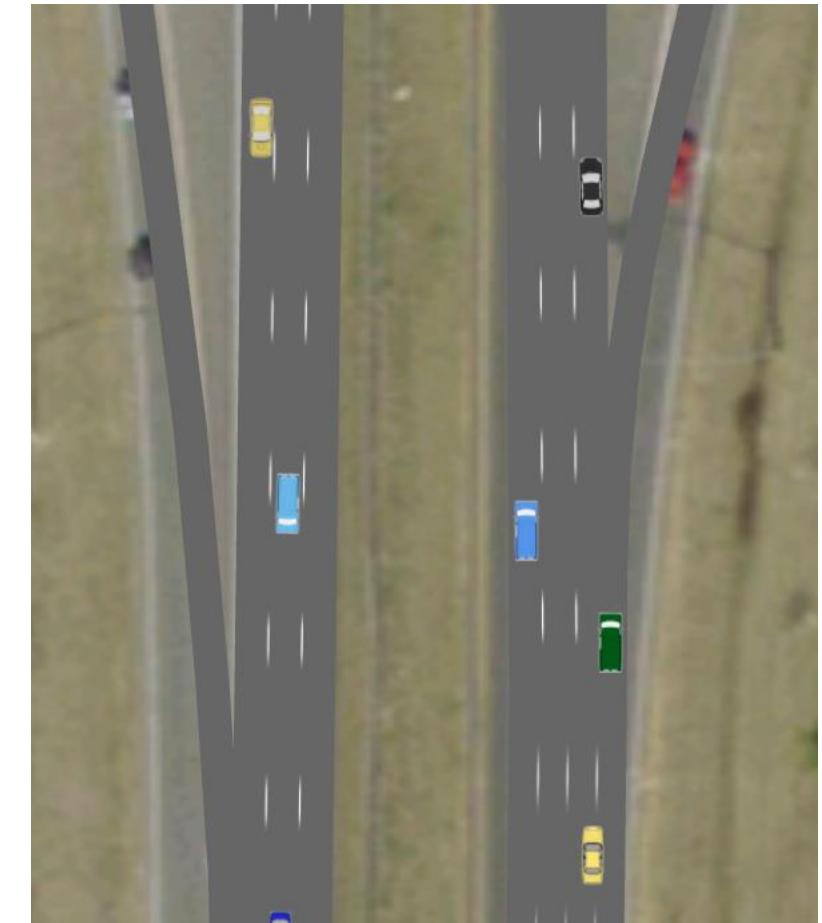
System / GIS / Simulation / Procedural / Data-driven
• GIS-based modelling

Kuntzsch2015



Street segment KDE, intersection with RJ-MCMC

Wilkie2012



Turning radius, network of lane, simulation

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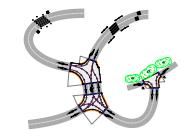
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State of the art: Existing models

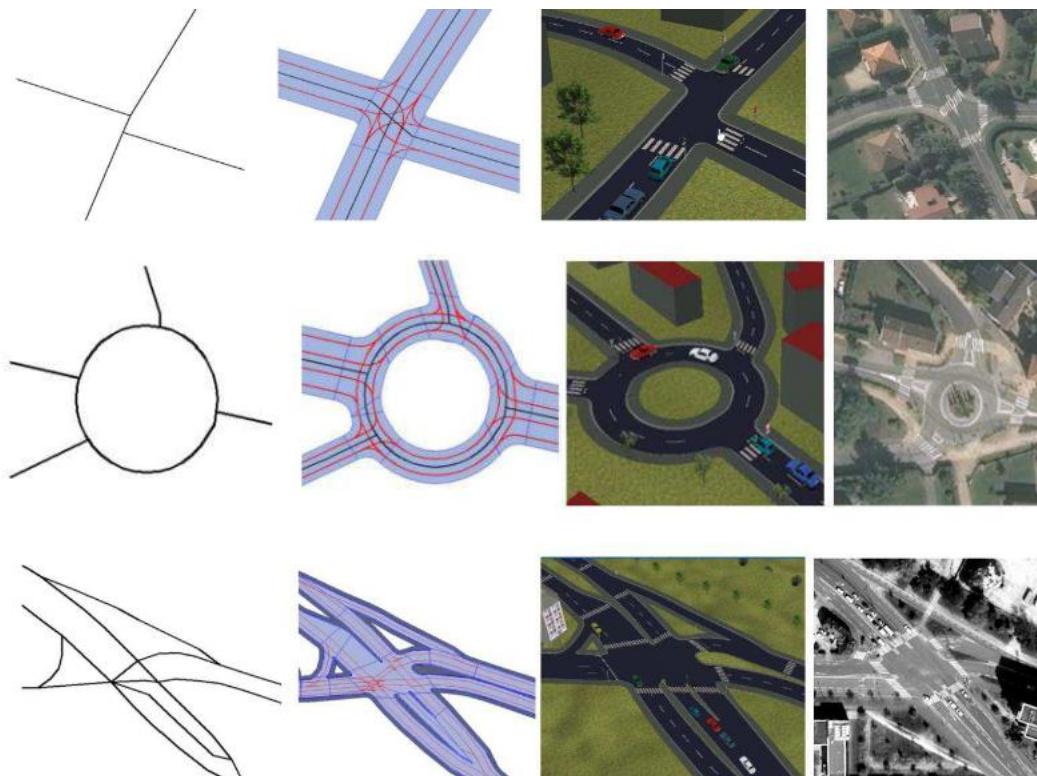
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System / GIS / Simulation / Procedural / Data-driven

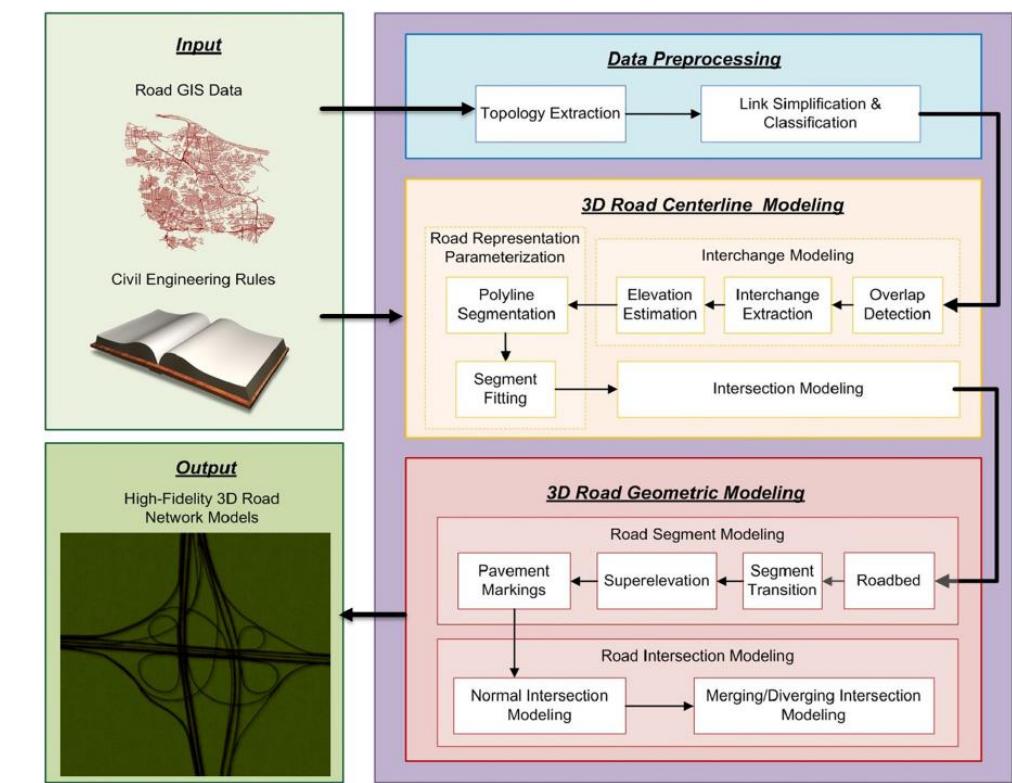
- Simulation-based modelling

Despine2011



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

Wang2015



Segment of road parametrisation, intersection...

State of the art: Existing models

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System / GIS / Simulation / Procedural / Data-driven

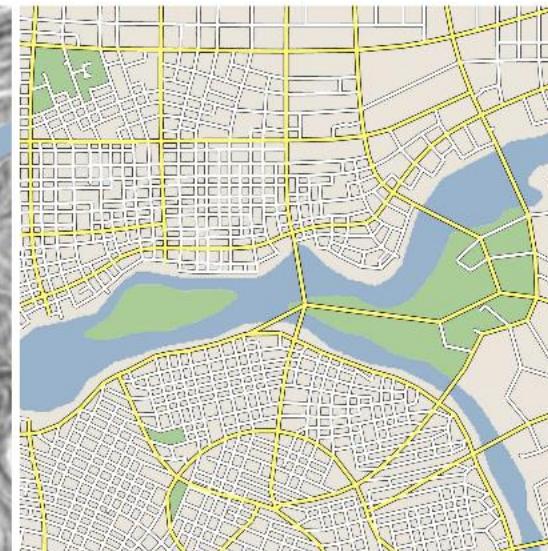
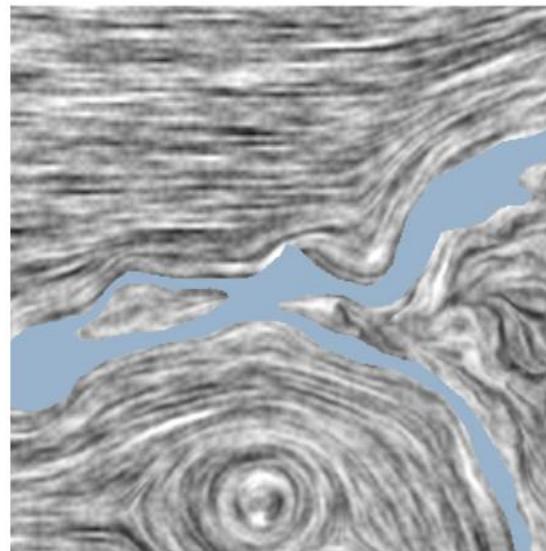
- Procedural modelling

Gallin2011



Terrain, graph : shortest path and merging,
procedural generation

Chen2008



Tensor, stream line, grammar

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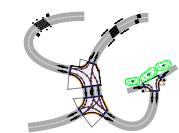
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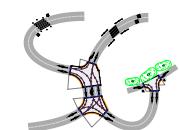
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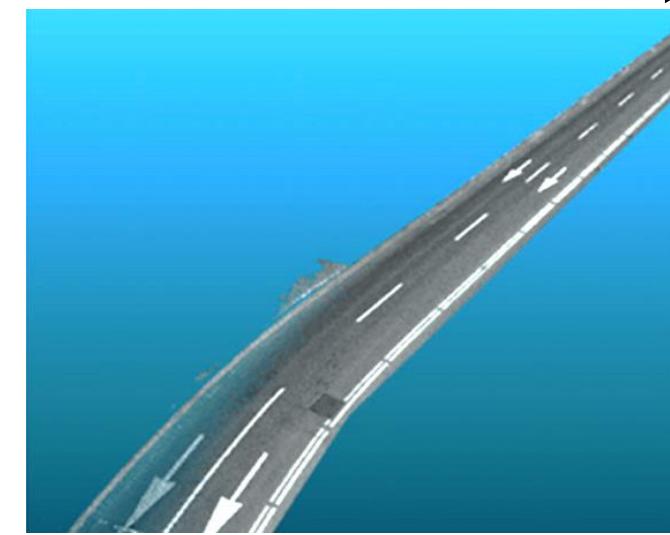
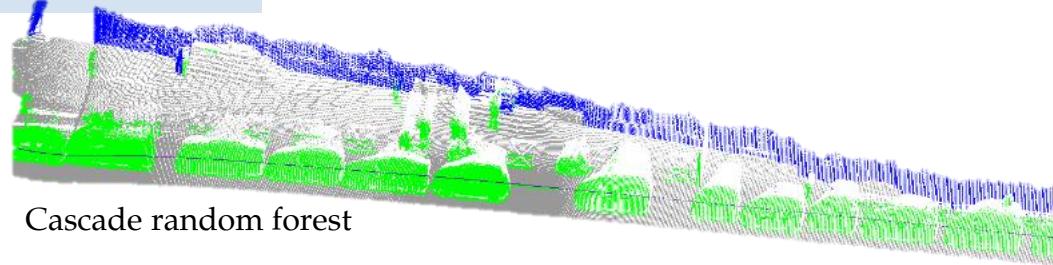


System / GIS / Simulation / Procedural / Data-driven

- Data-driven modelling
 - From image/lidar

Guo2015

Serna2015



Extraction, raster, template matching

Boyko2011

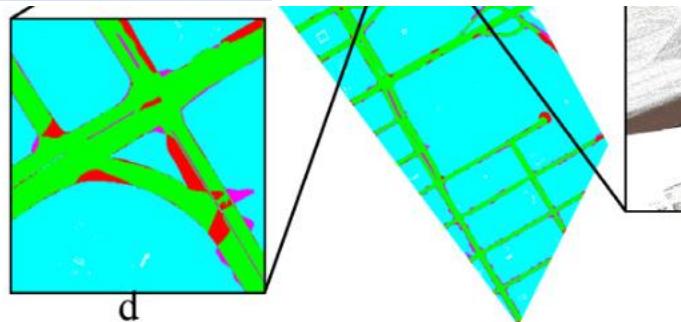
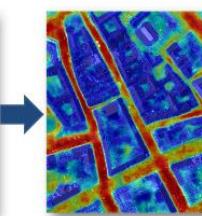


Fig. 9. Classification error map.

Fitting + active contour



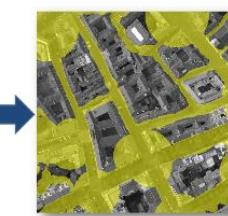
Context-aware road scores
(Section 3.1)



Road likelihoods
(Section 3.2)

Montoya-Zegarra2014

Classif + Context + CRF



State of the art: Existing models

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

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start_node=4 ...

System / GIS / Simulation / Procedural / Data-driven

- Data-driven modelling
 - From aerial imgs

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

Todo : detailed ref for
remote sensing from
images

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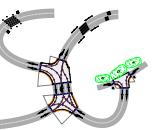
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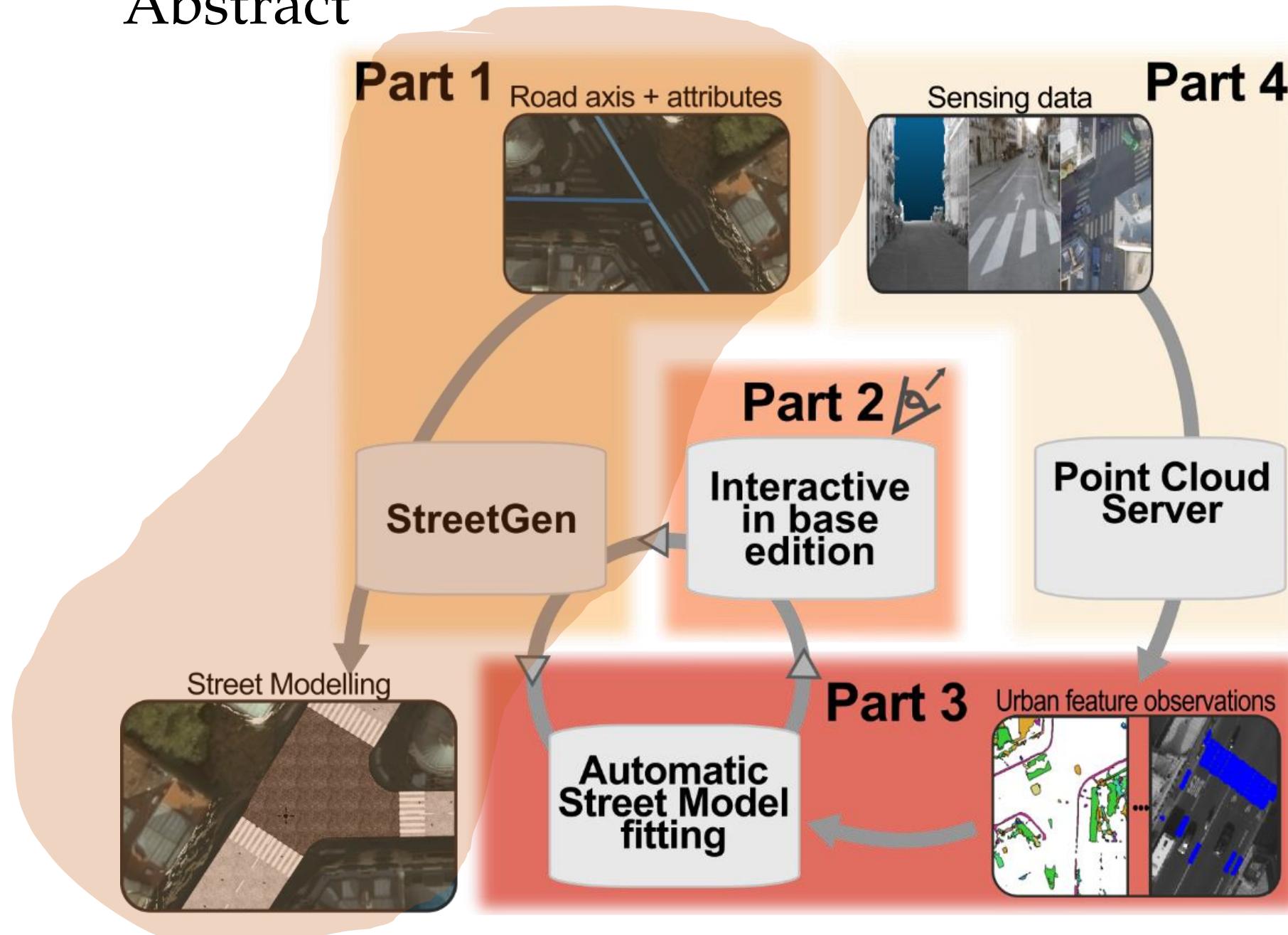
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Abstract



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StreetGen : generate streets

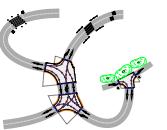
Design Principle

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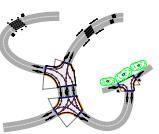
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- To Design = to compromise
- Goals?
 - Model streets of whole Paris (scale, robustness)
 - Work with limited GIS data (best guess)
 - Model used for various outputs (analysis/ 3D visu / traffic simulation...)
- Our approach:
 - Limited data : based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

StreetGen : design principle

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

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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

StreetGen : graphical abstract

edge_id= 15; next_l= 16
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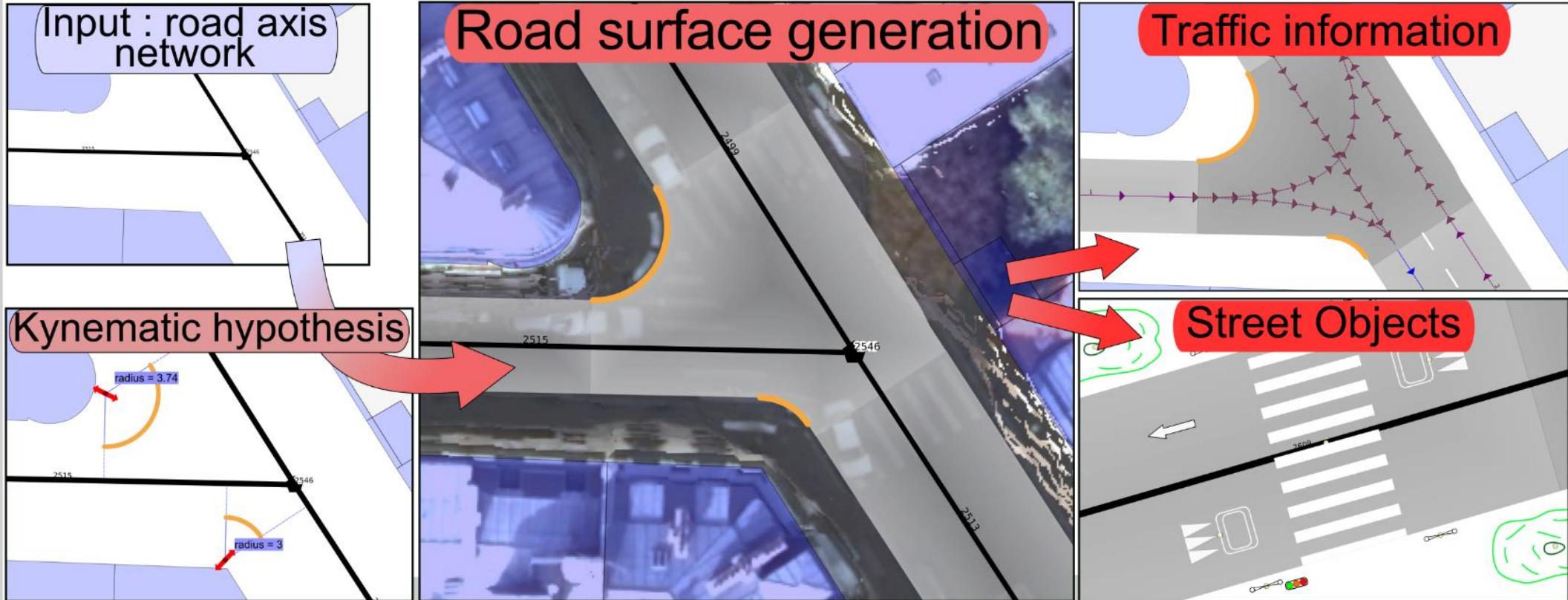
Automation

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SG

StreetGen graphical abstract ↗



database server

StreetGen : design principle

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

start_node= 4 ...

- StreetGen road model

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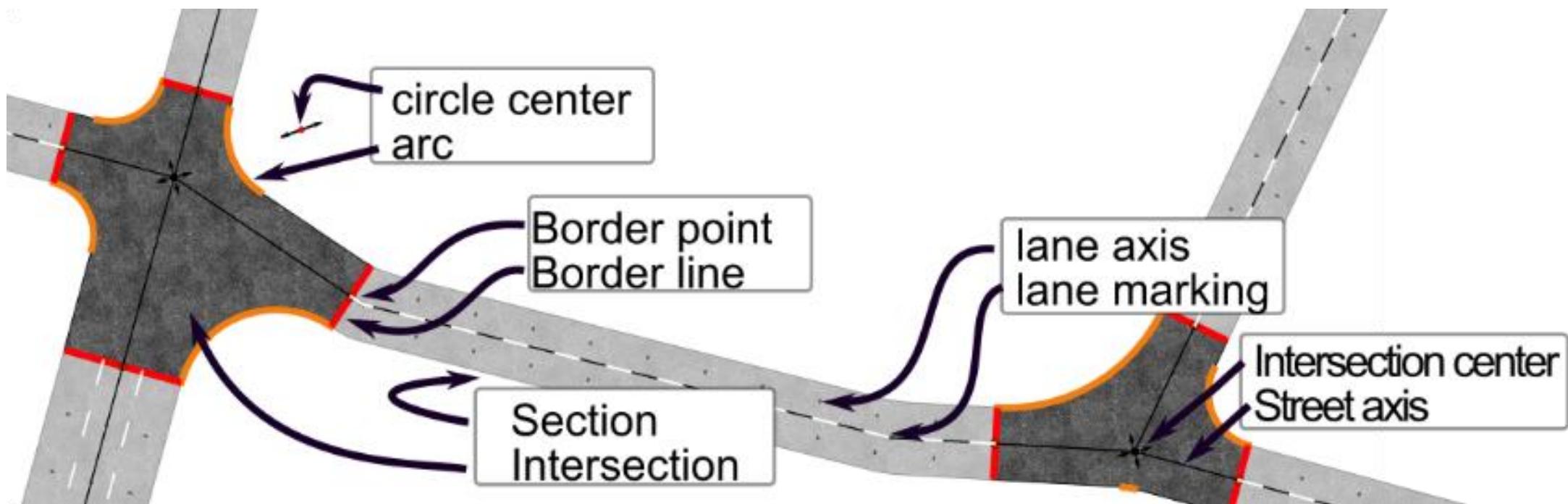
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StreetGen : design principle

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How to deal with several users?
Use a RDBMS !

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

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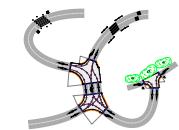
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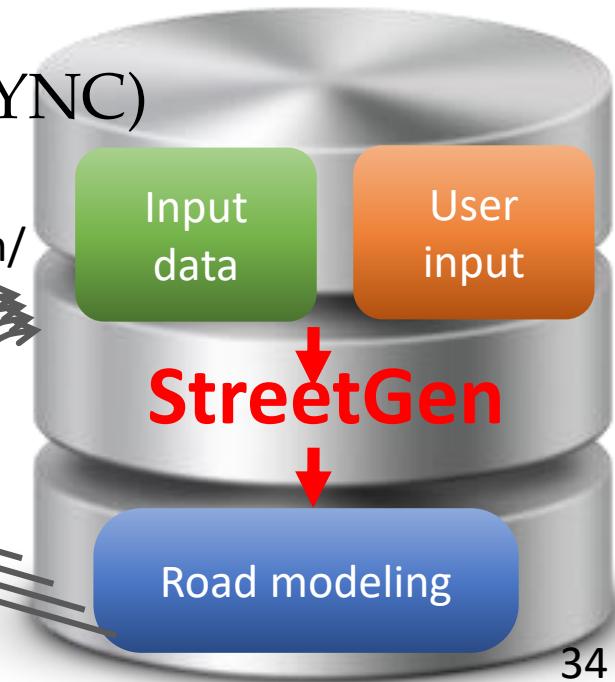


UPDATE MODELING (SYNC)



Ask computing on/
edit

Visualize



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start_node= 4 ...

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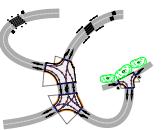
Automation

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StreetGen : generate streets

Design Principle
Kinematic hypothesis
Road surface
Traffic support
Street objects



StreetGen : Kinematic hypothesis

edge id=15; next_l=16
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edge id=16; next_l=17
start_node=4 ...



- Kinematic hypothesis

width

Road type
↓
speed
↓
radius



3m

↑

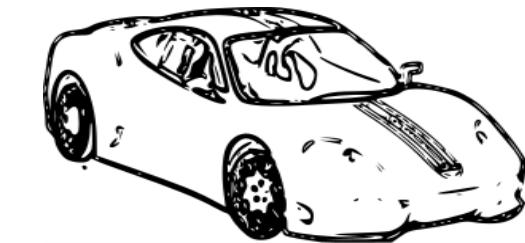
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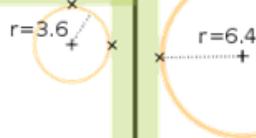
↑

9m



StreetGen : Kinematic hypothesis

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



- Various radius in Paris

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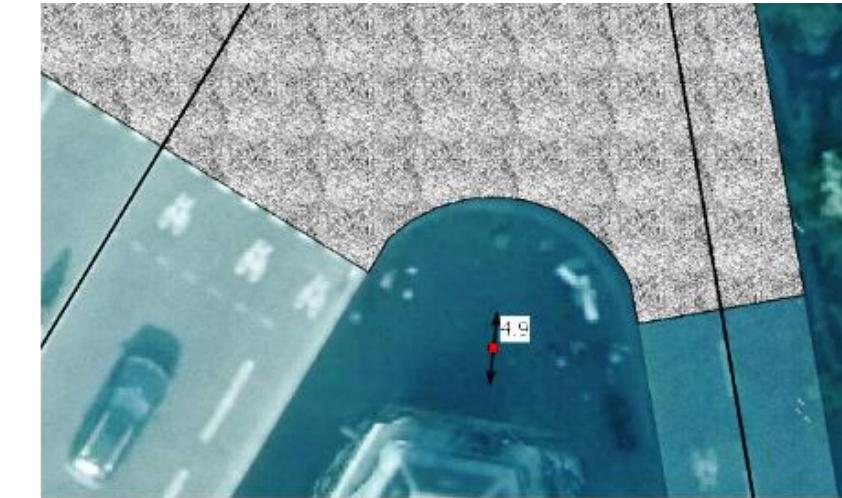
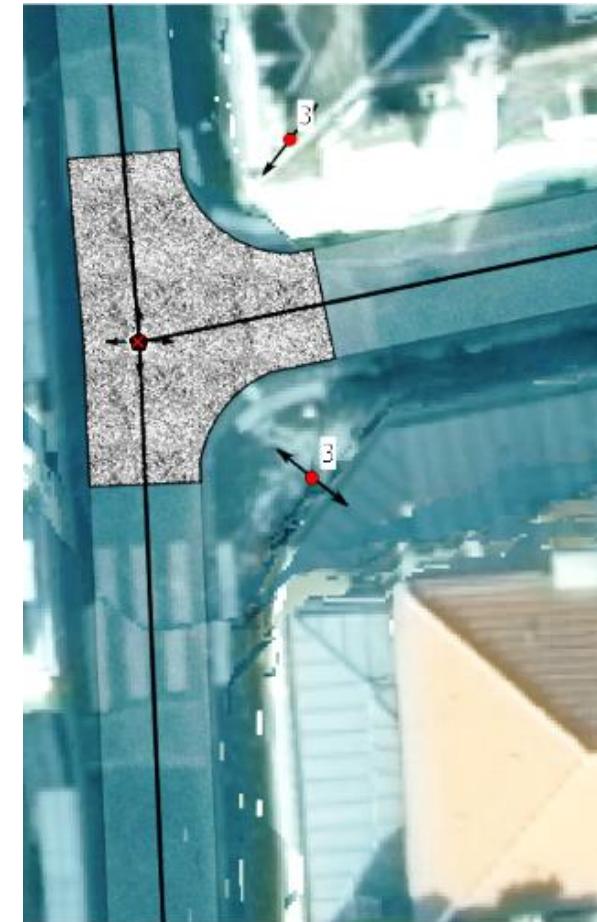
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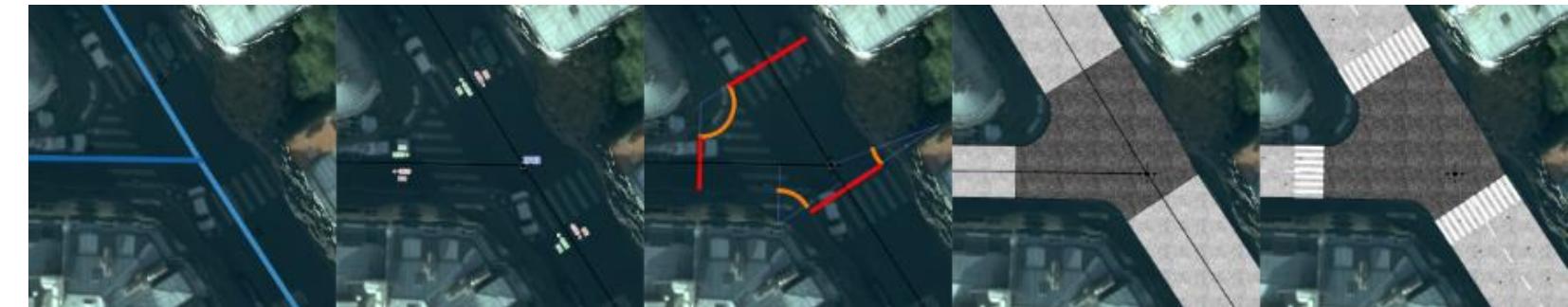
edge id=15; next_l=16
end_node=3 ...



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

StreetGen : generate streets

Design Principle
Kinematic hypothesis
Road surface
Traffic support
Street objects



StreetGen : Kinematic hypothesis

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

\bullet t

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

r=3.6

r=6.4

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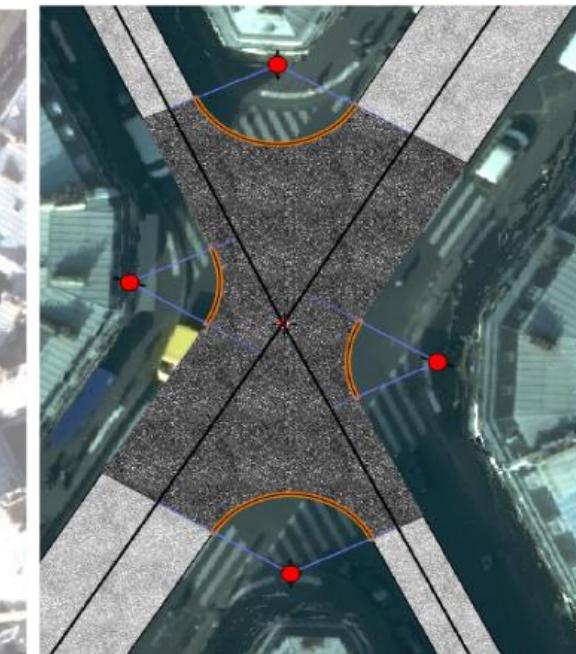
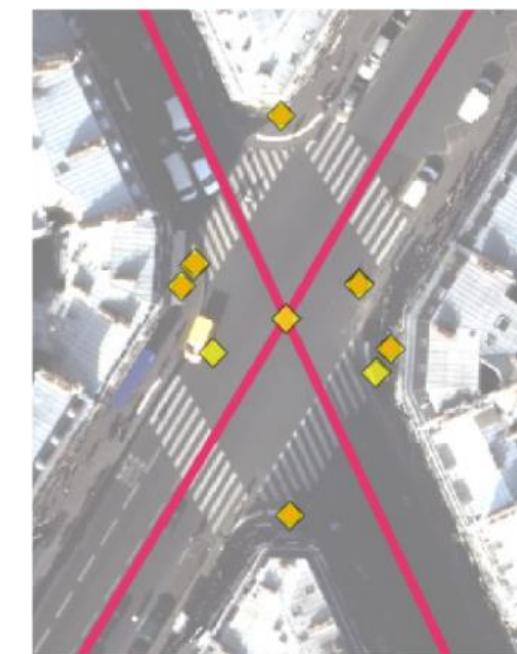
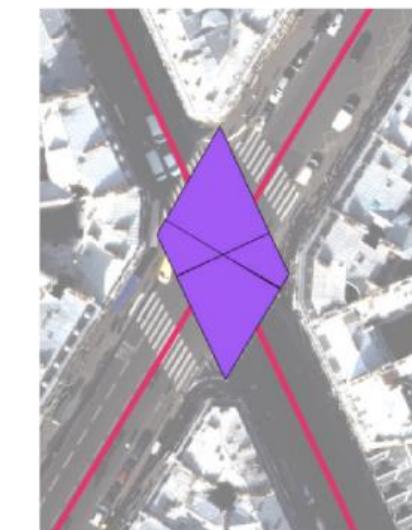
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StreetGen : Road surface

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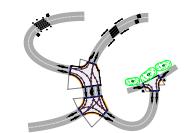
Streets

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```

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

$r=3.6$

+

+

```

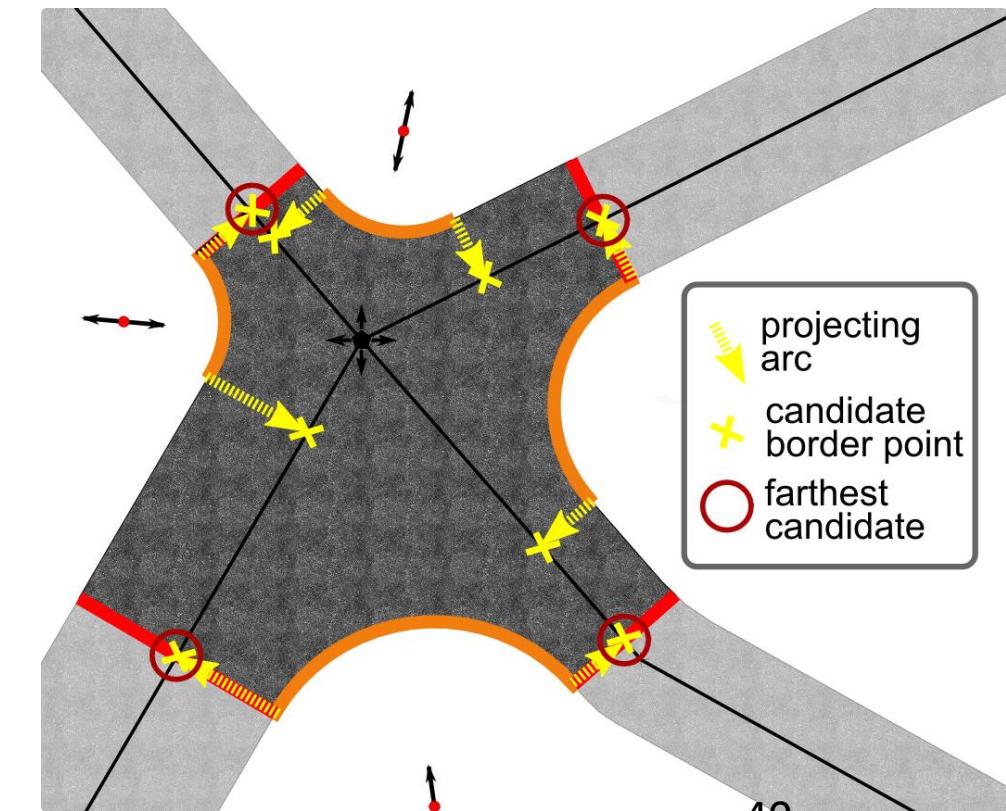
edge_id=17; next_l=16
start_node=4 ...
  
```

+

+

- Find intersection limit :

- Project circle centers
- Farthest per axis



StreetGen : Road surface

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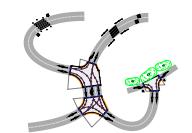
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edge id=15; next_l=16
end_node=3 ...

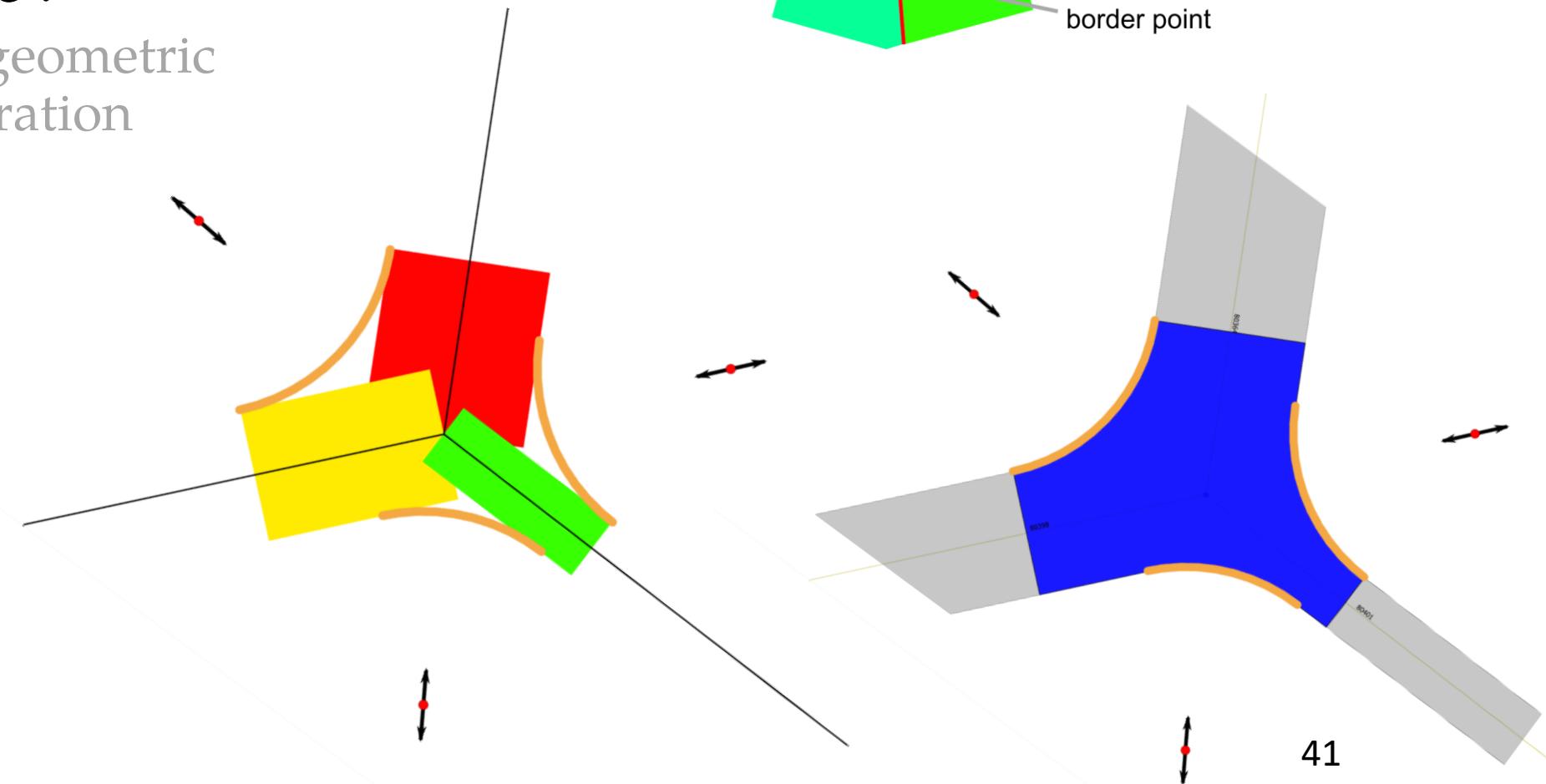
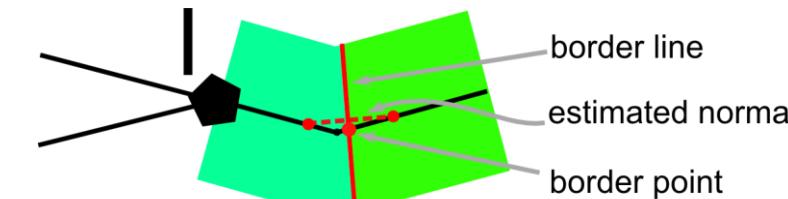
edge id=16; next_l=17
start_node=4 ...

r=3.6 +

r=6.4 +

- Create Intersection surface :

- By geometric operation



StreetGen : Road surface

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

- Special intersection:
- Variable buffer
- No other parameter for road width reduction control

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

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

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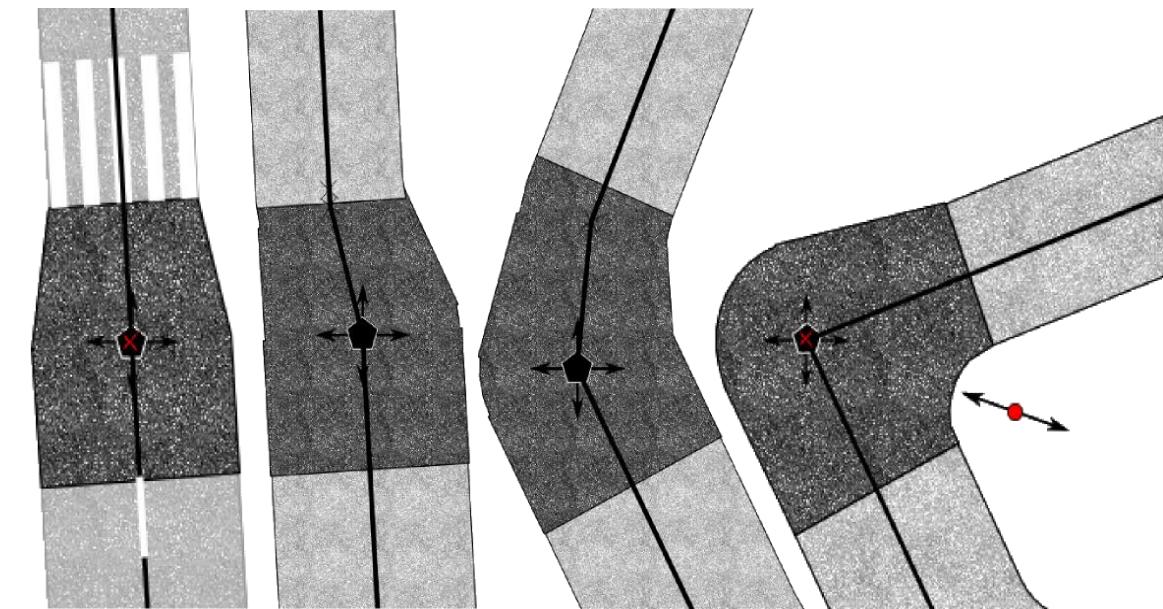
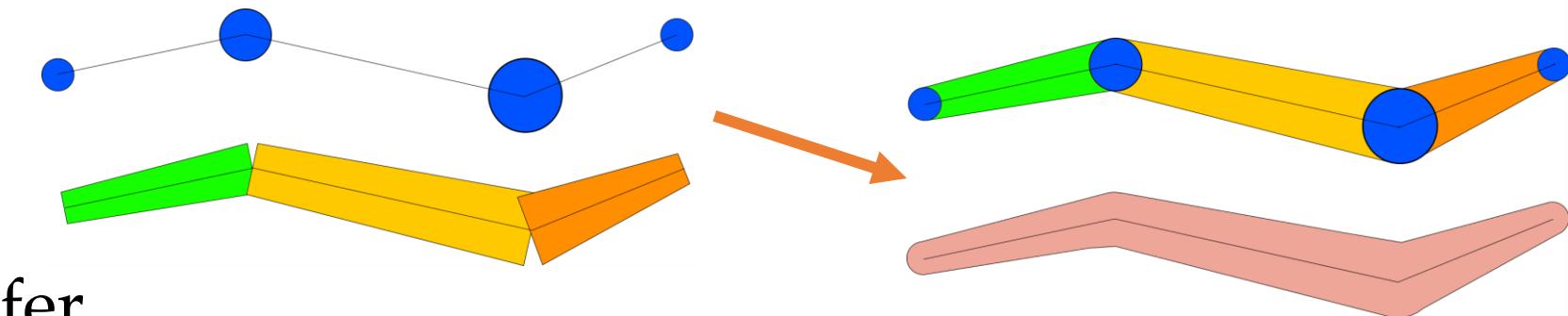
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StreetGen : Road surface

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

- results

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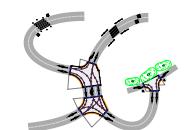
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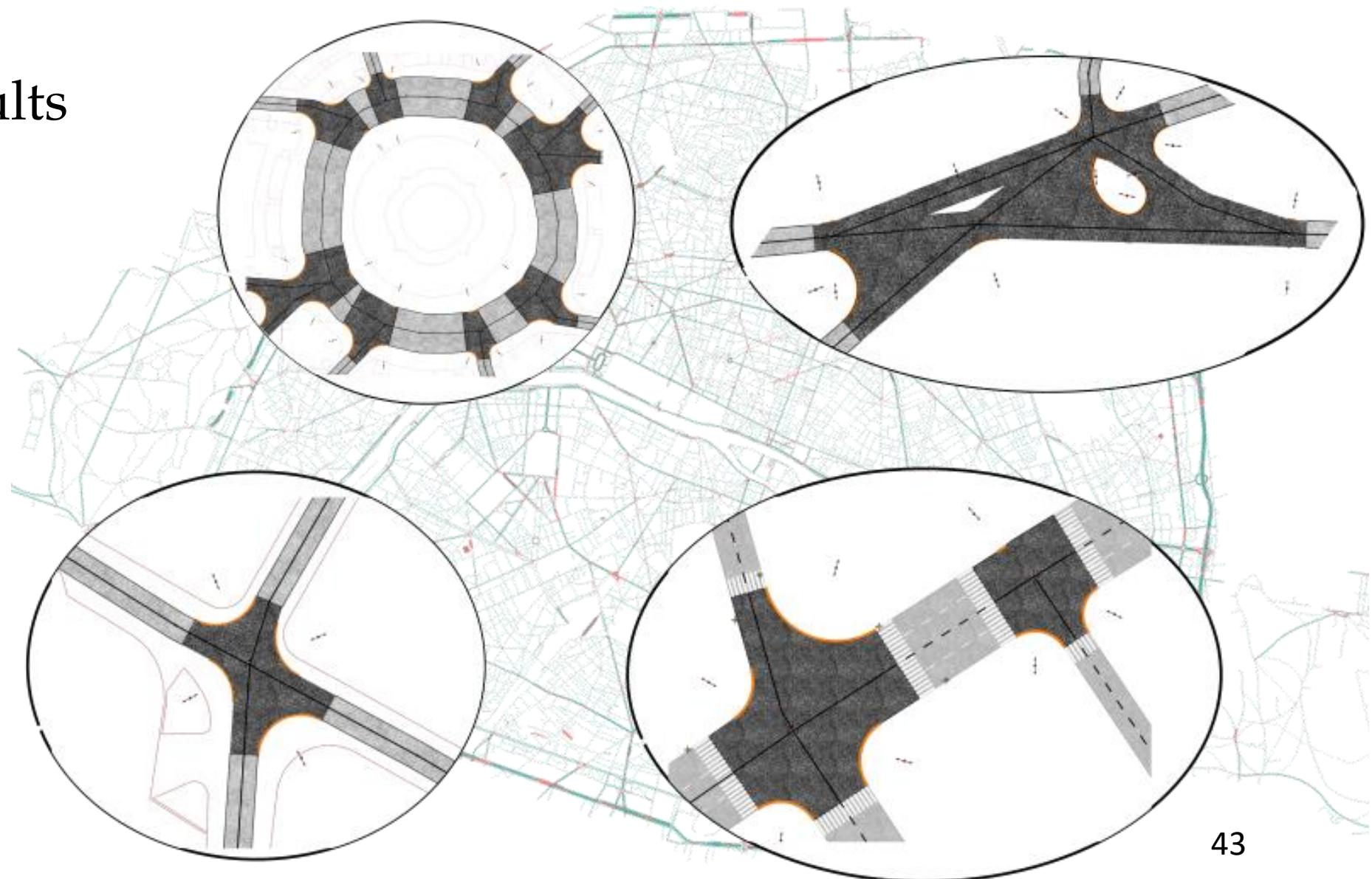
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edge_id=17; next_l=17
start_node=4 ...



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

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

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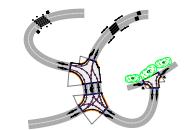
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StreetGen : Traffic Support

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- For traffic simulation:
 - Lanes
 - Possible trajectories in interconnections.
- Traffic simulation requires much more
 - Average speed
 - Type of intersection (roundabout/traffic light)
 - Etc ...

StreetGen : Traffic Support

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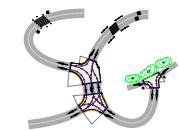
Streets

Interaction

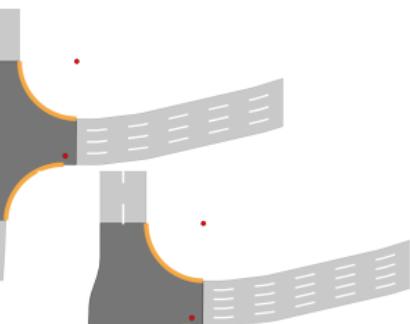
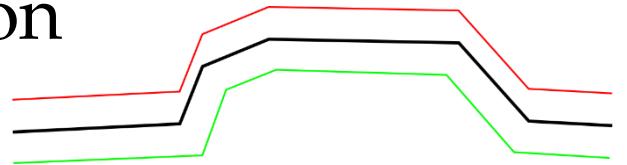
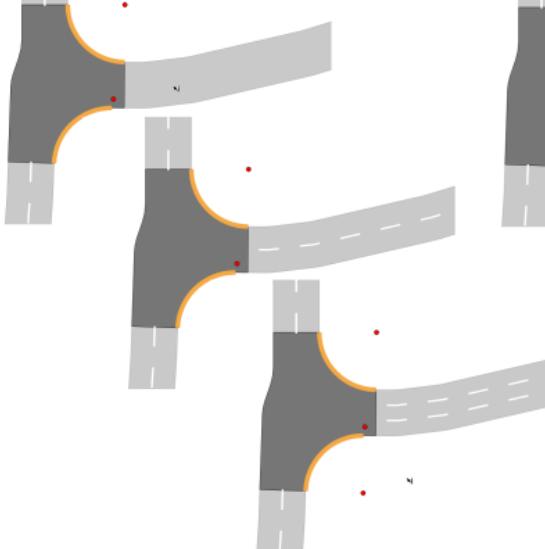
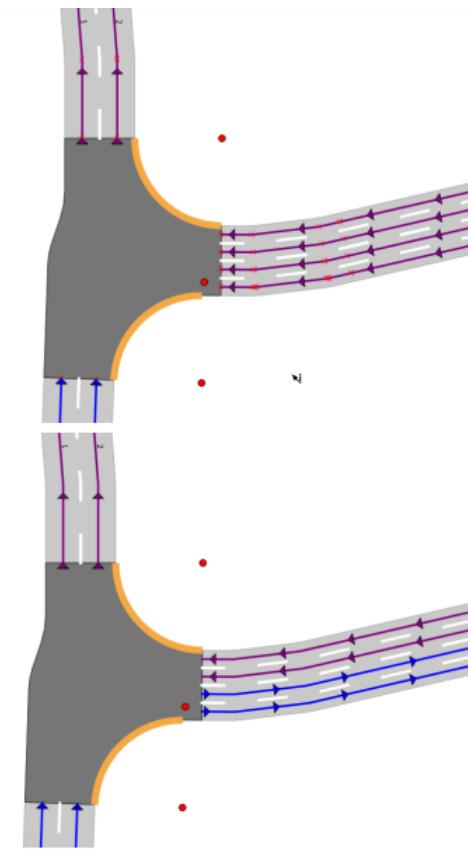
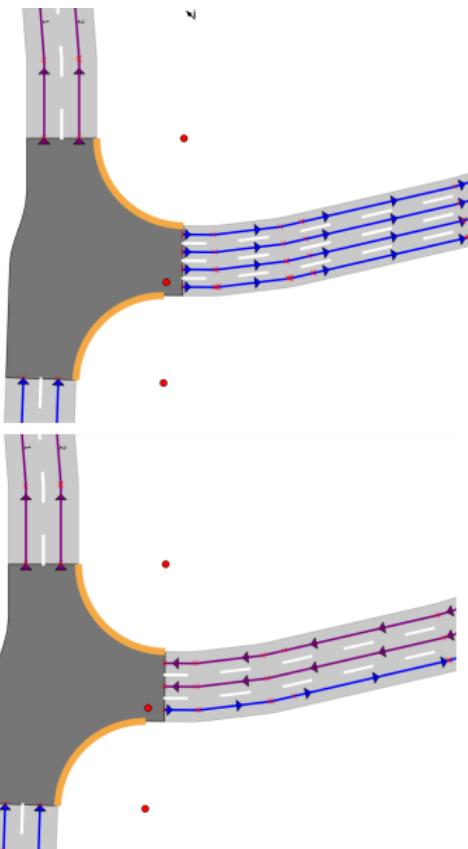
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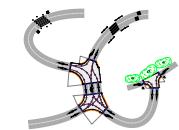


- Lane based on road axis : but not translation

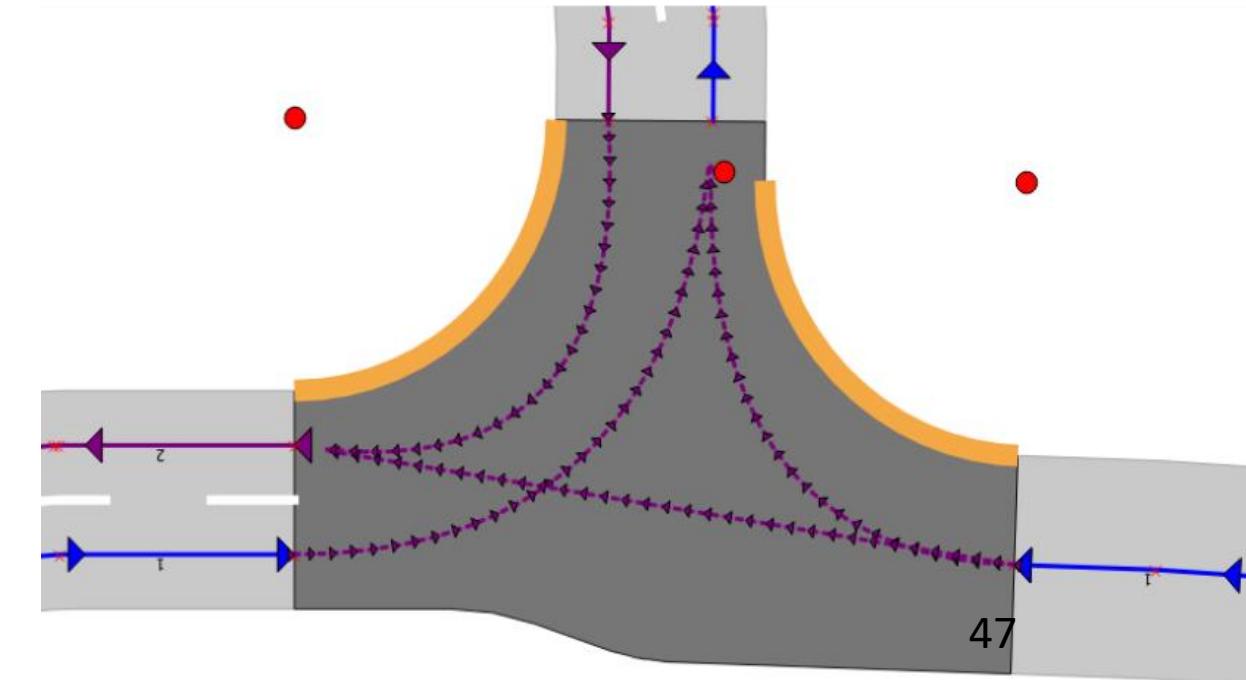
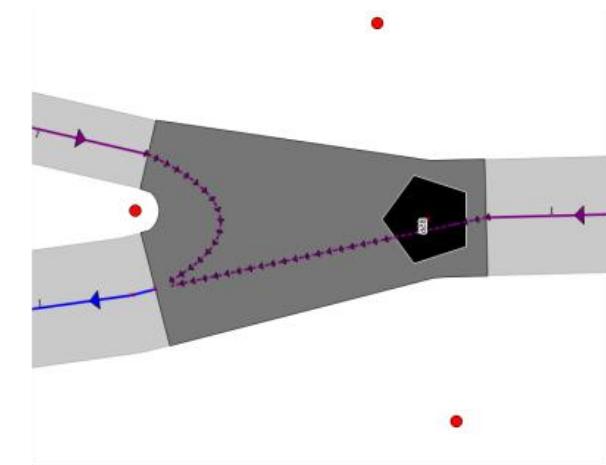
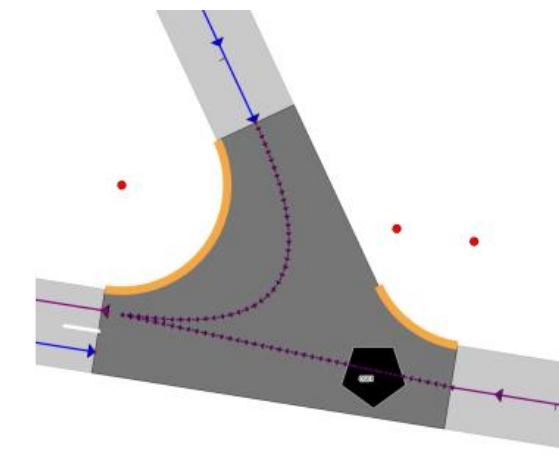


StreetGen : Traffic Support

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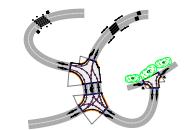
- Intersection trajectory : Bezier curves:
 - Not accurate (cinematically), but easy to create and edit
 - Involves center of intersection in special cases
 - Direction coherent with lane direction





StreetGen : street objects

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- Streets objects : incredibly varied
 - 13k references on www.ArchiExpo
 - Norms : Instruction Interministérielle sur la signalisation routière : 1000 pages
 - ...
 - Objects are in relation (hierarchical, spatial, semantic ...)
 - Not many common points between all kind of street objects
- Street objects are often spatially organized (position and orientation)relatively to the street axis

Im: random objects

StreetGen : street objects

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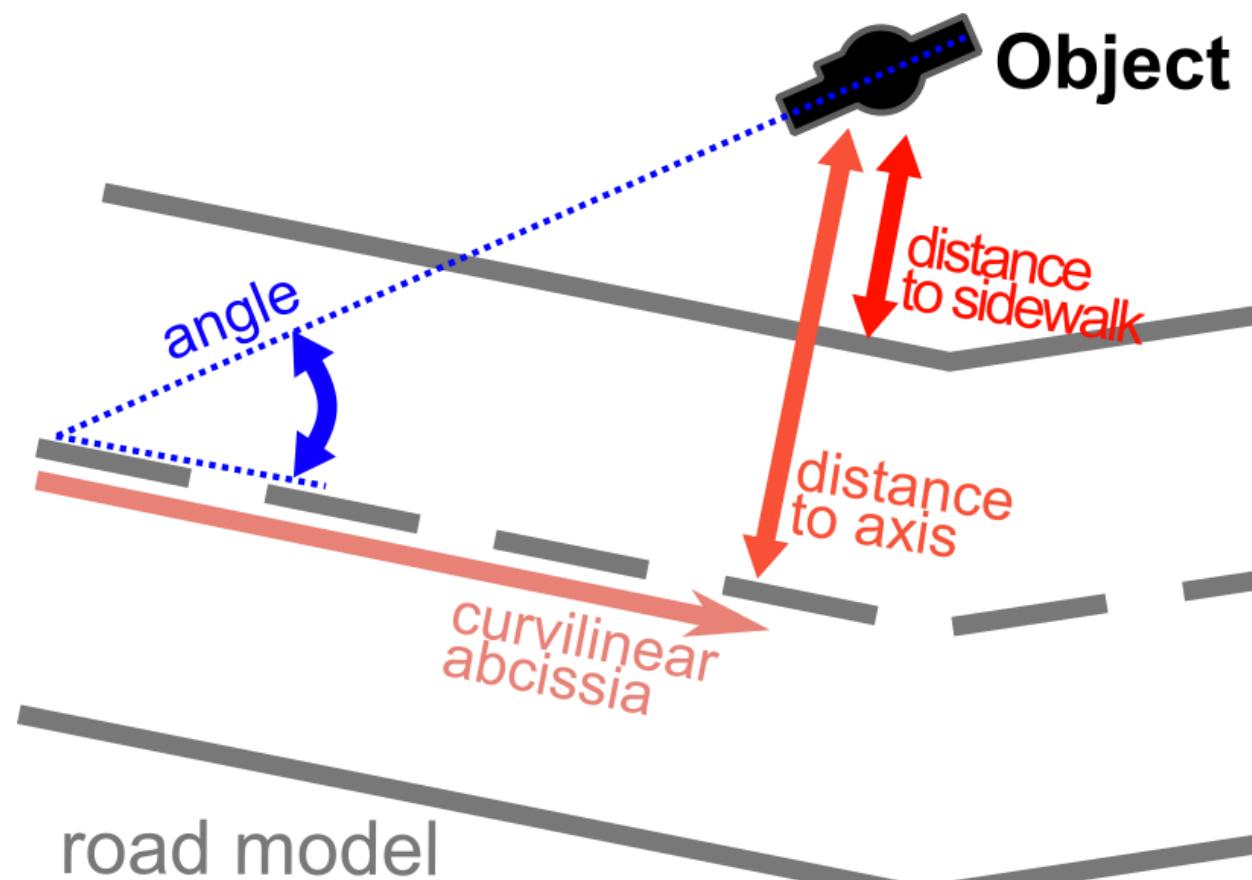
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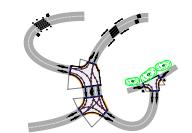
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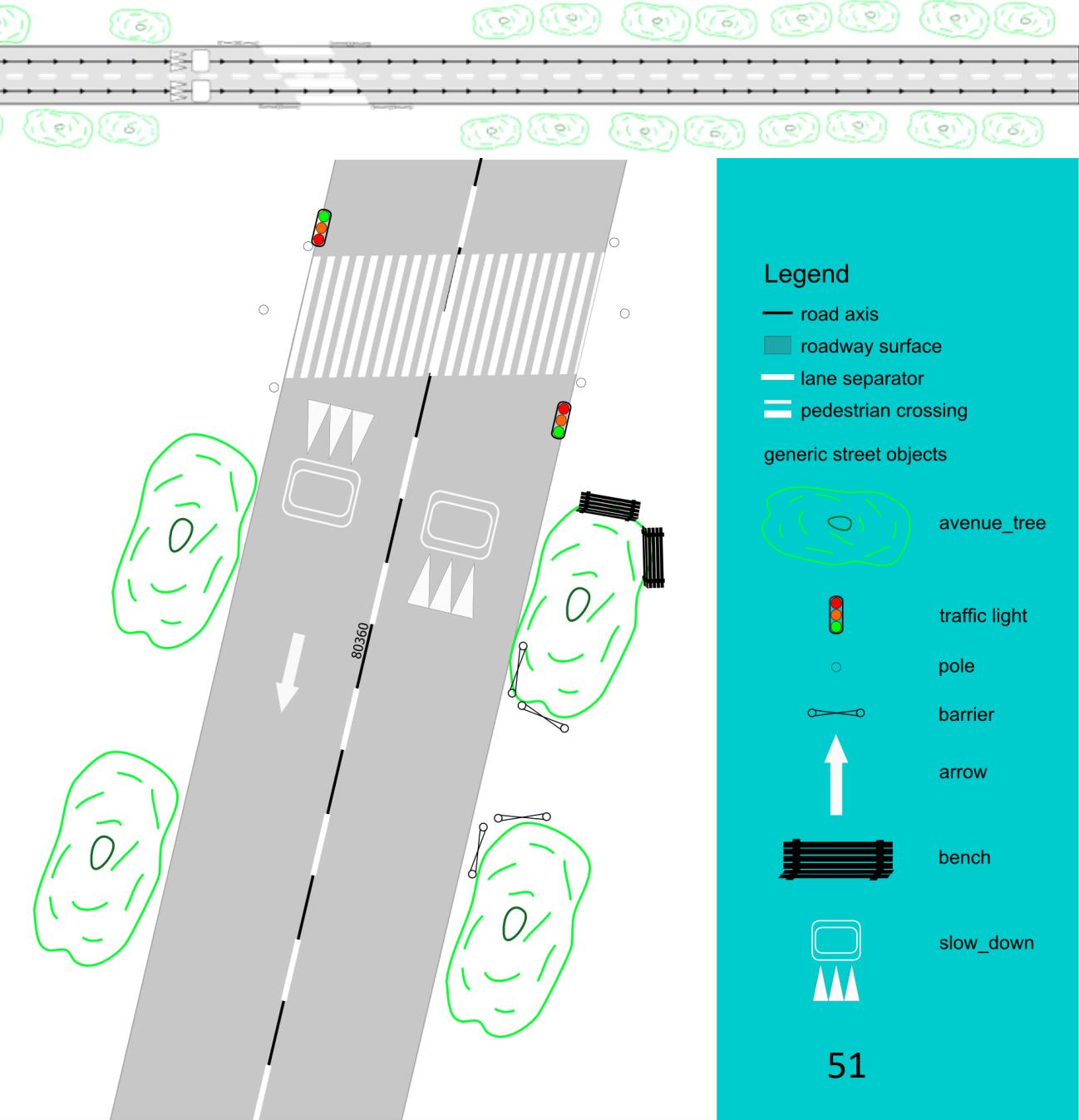
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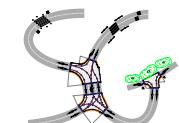


- Objects are **points** with semantic
- DBMS can support any relation (hierarchy, semantic...)

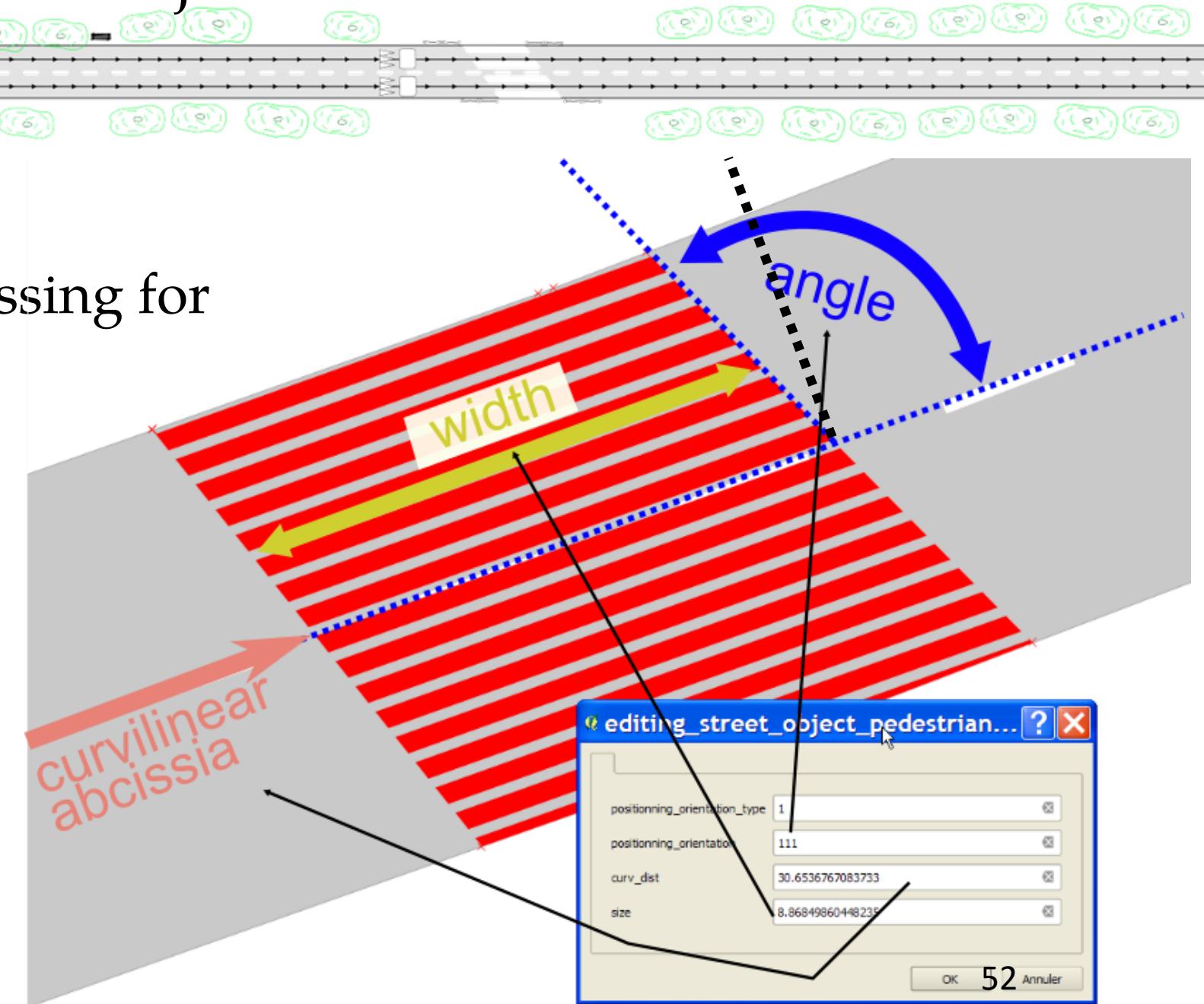


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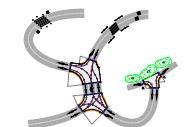


- Also surface
- Pedestrian crossing for instance

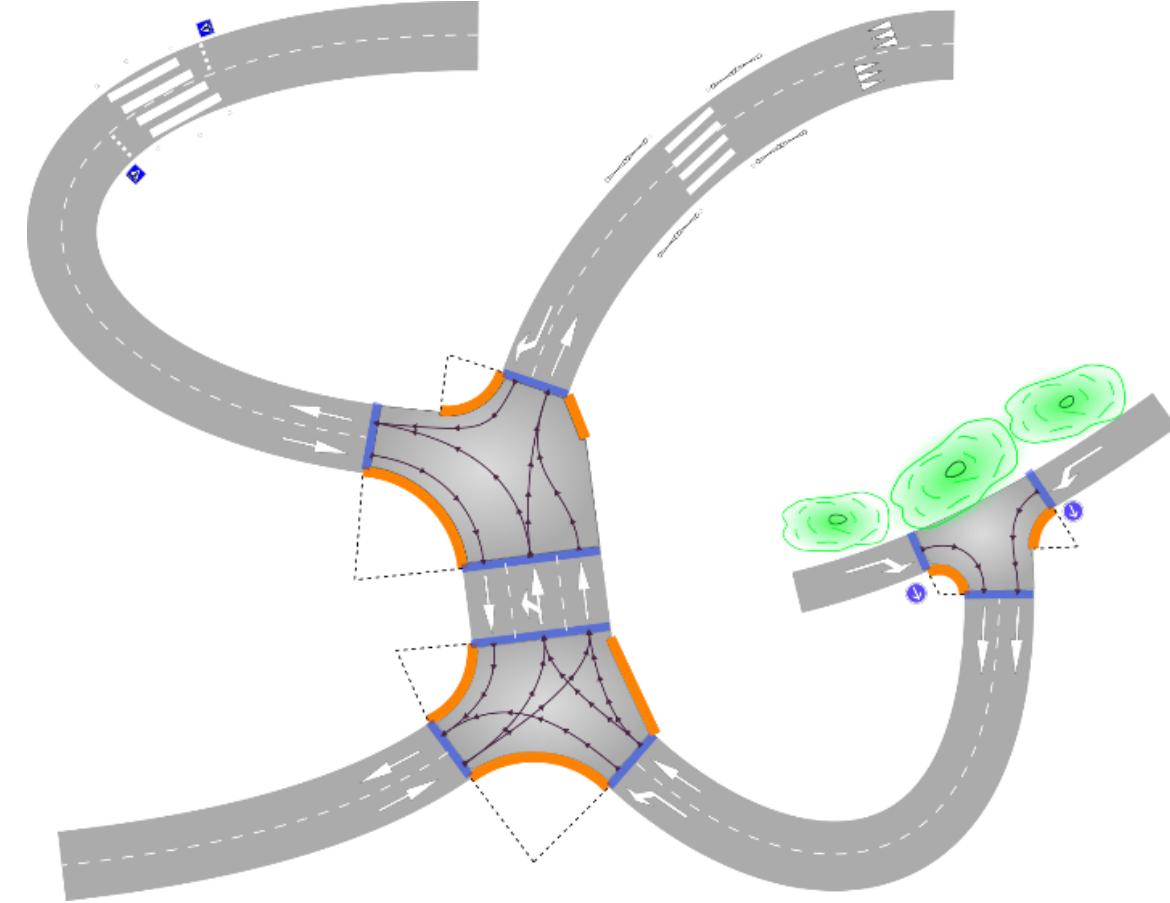
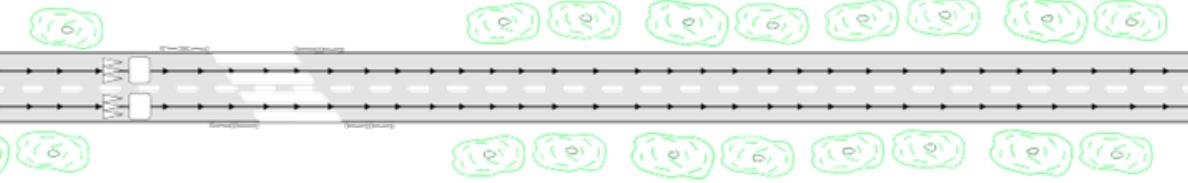


StreetGen : street objects

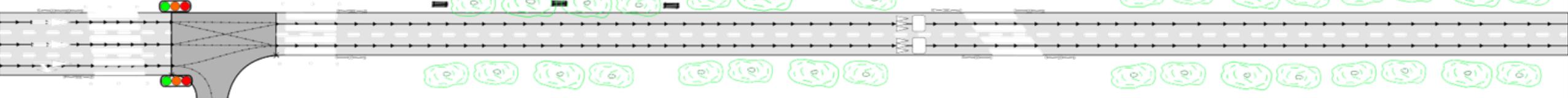
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- Whole Paris in 10 min.
- Tested for simulation (SimuVia)
- Tested for 3D visu (Thales NeoDBGS)
- Tested to model other cities (West Africa)
- Tested to model airport runway



StreetGen : street objects



Contributions

- Data, method, result in RDBMS
- Robust surface computing
- Fast & scale well

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StreetGen : street objects

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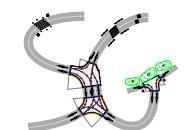
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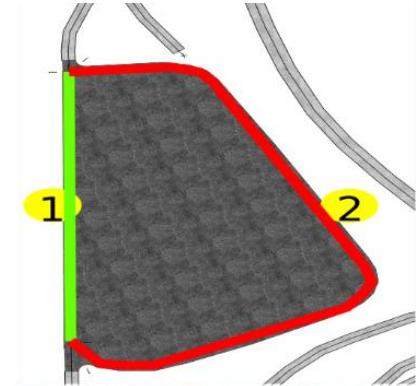
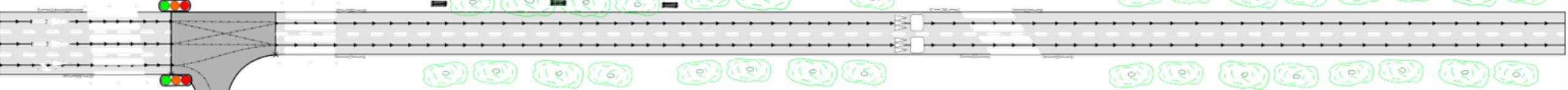
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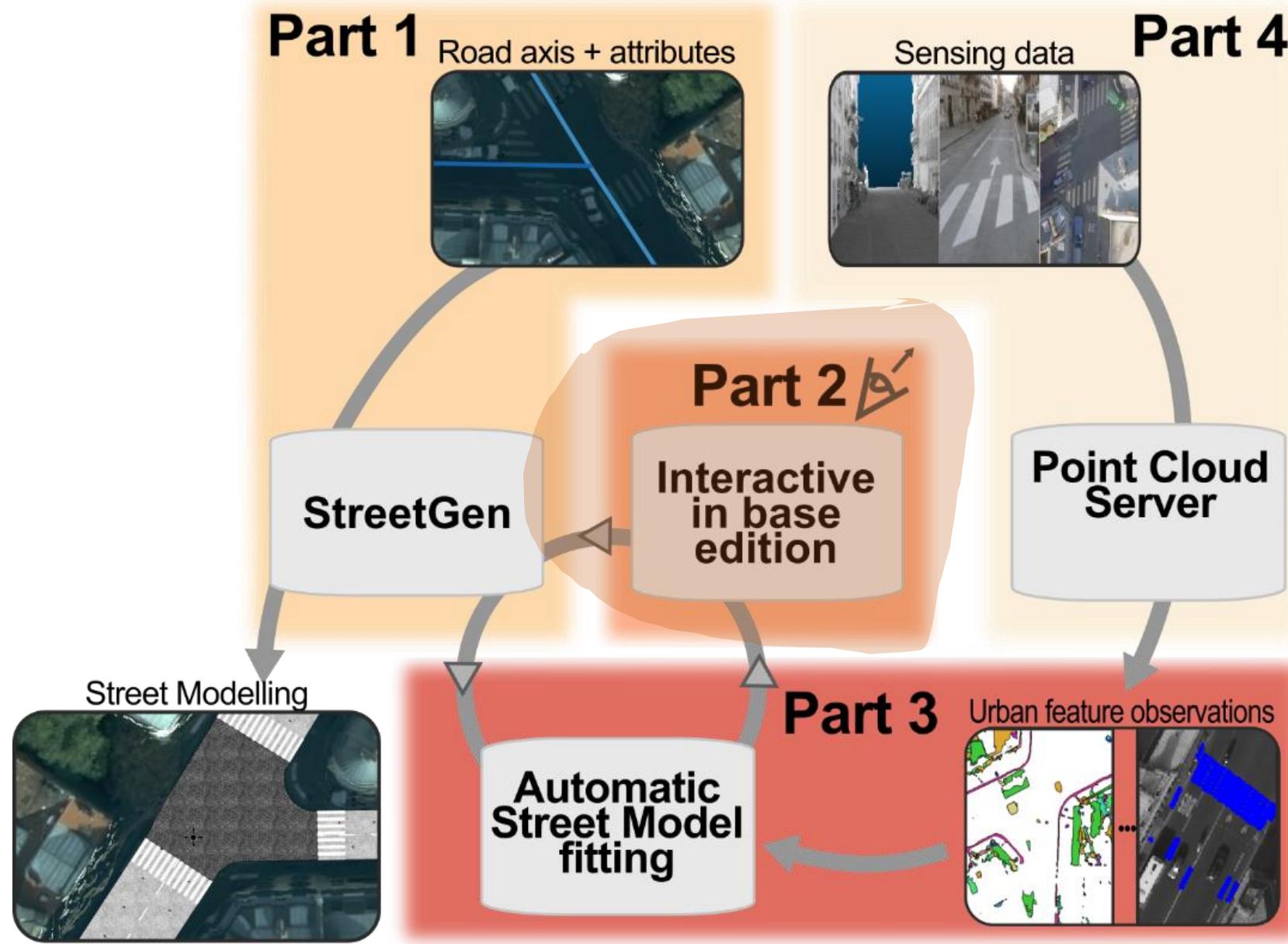


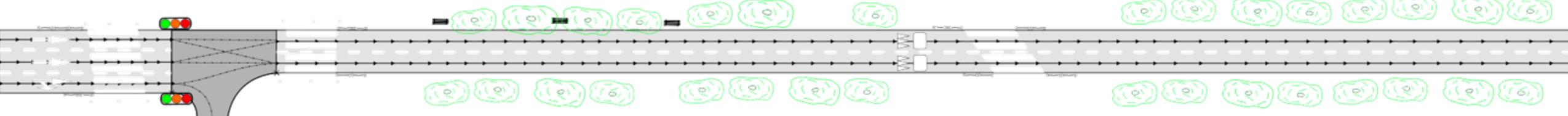
Of course, lot of limitations

- Street model:
 - Not enough for some street
 - Radius seems to be historical rather than related to speed
- Technical
 - Precision issues
- Objects
 - Lack linear objects



Abstract



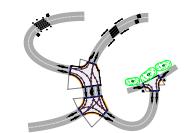


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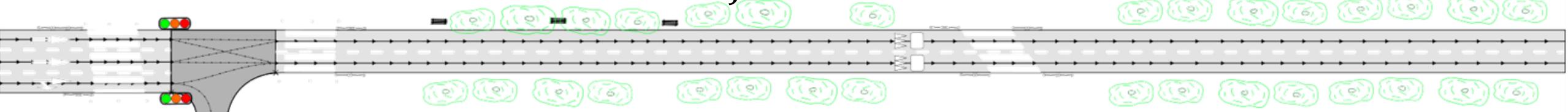
StreetGen : editing streets (in-base)

In-base interaction Principle

- Edit road model
- Edit traffic
- Edit objects



StreetGen : street objects



- How to edit street model easily?

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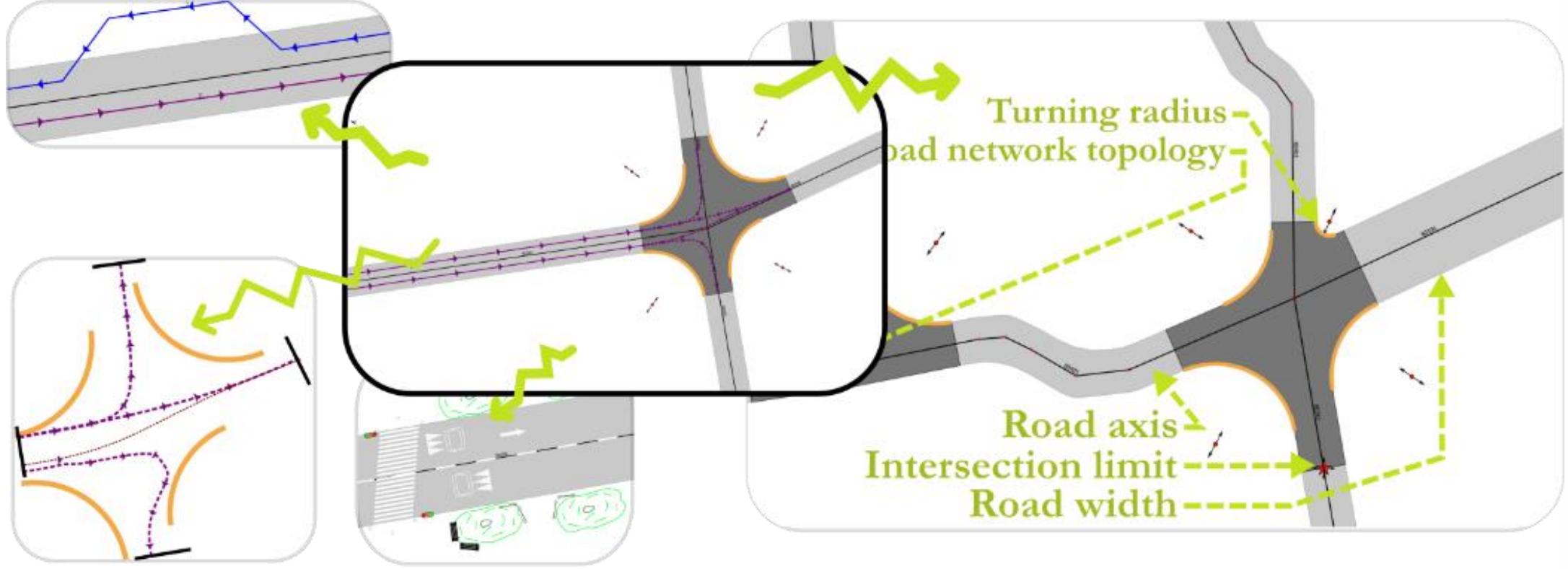
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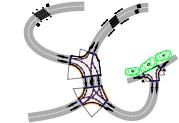
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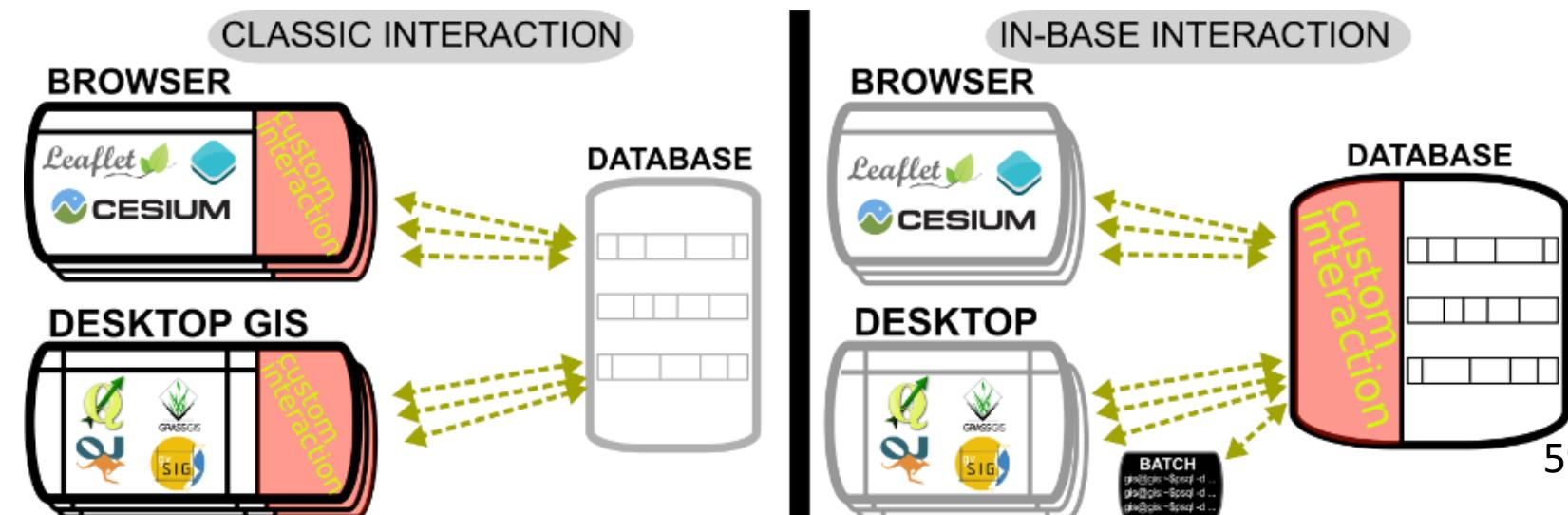


StreetGen : street objects

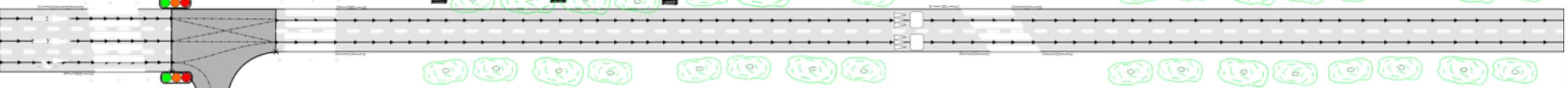
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- Fact : Graphical User Interface (GUI) → hard
- Many GUI for many tools (web/desktop/...)
 - Need to create plugins/interfaces/...
- Use existing tools !
 - GIS tools can already edit vector and attributes
 - specific interactions are in base



StreetGen : street objects



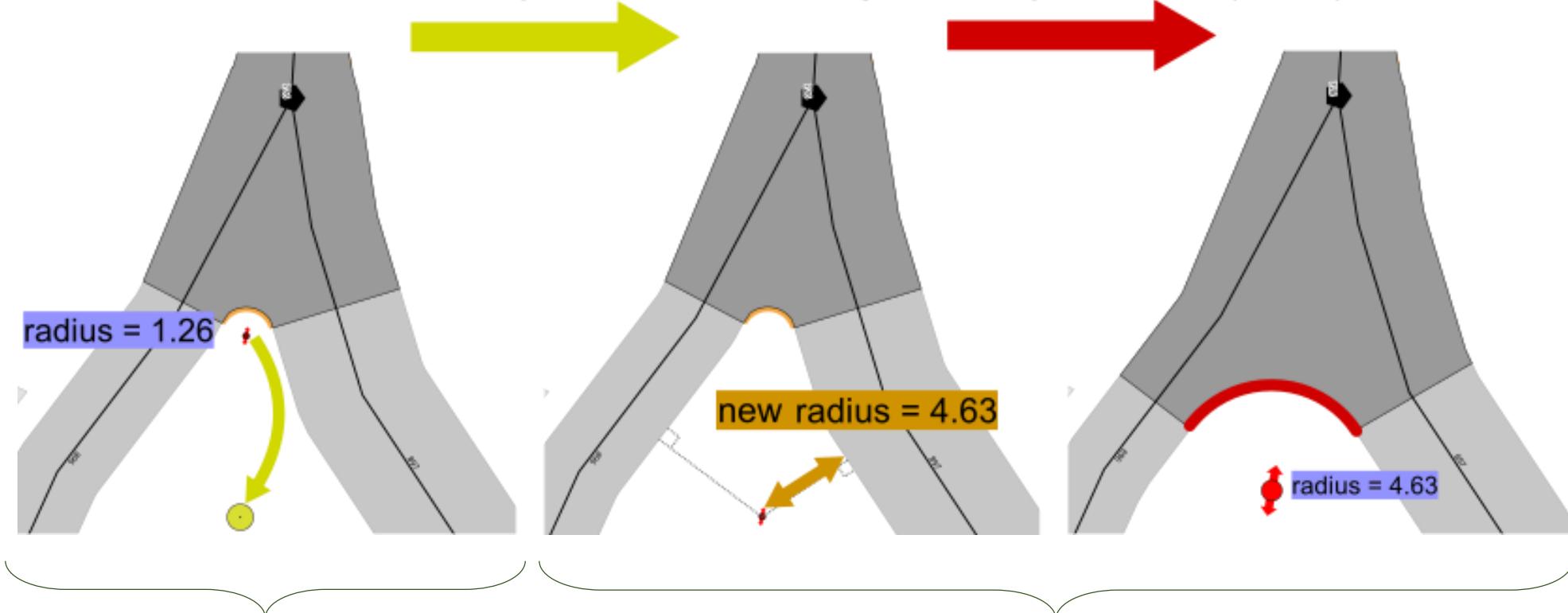
- example:

User

User edited proxy view:
interpret to get new radius

Automated

Radius has been changed :
generate geometries (arc ...)



StreetGen : street objects

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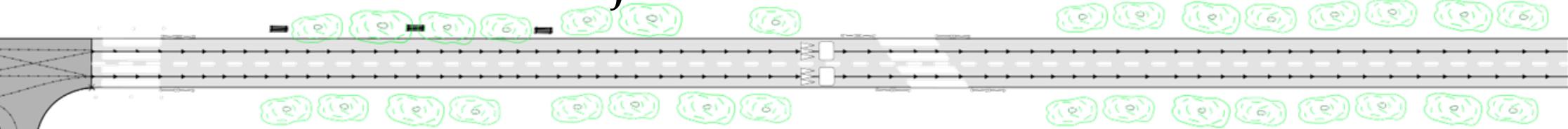
Streets

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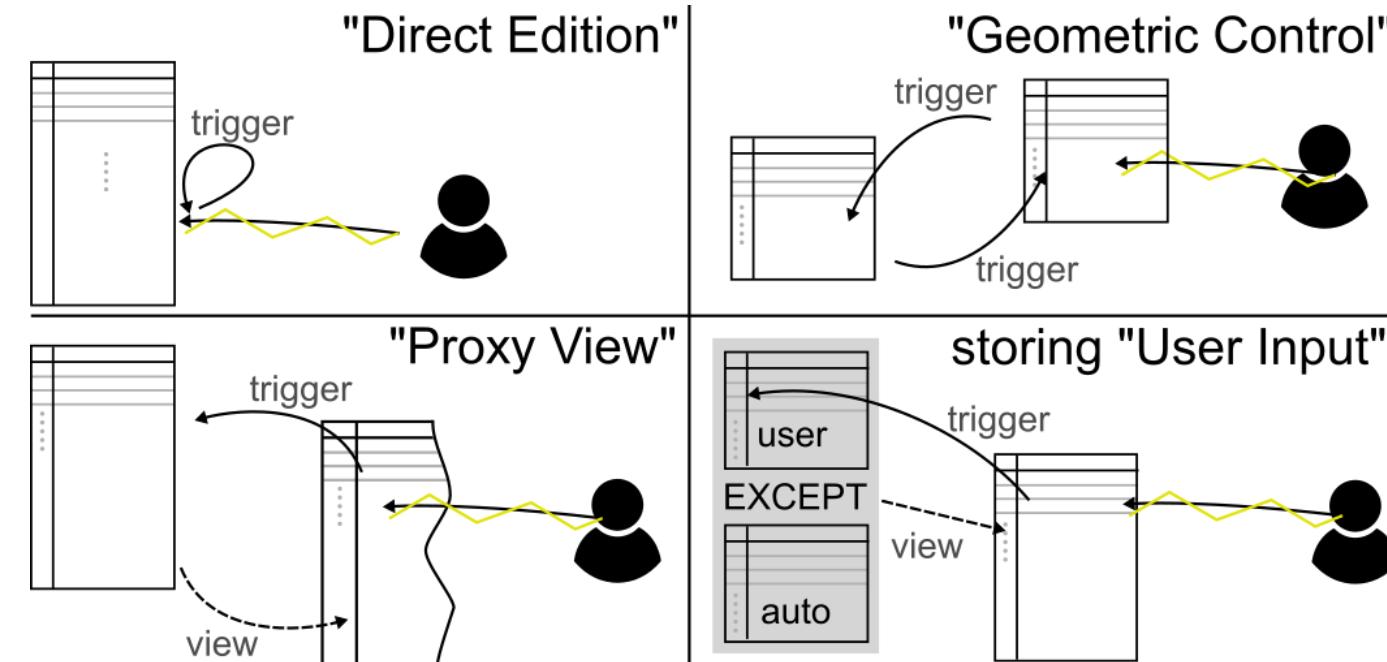
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- In-base interaction are generic and powerful
 - Design pattern to help use it for other applications



StreetGen : street objects

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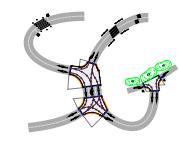
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- All StreetGen street model can be edited concurrently

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

① Assign curbstone points to road surfaces

② Compute new width (median)

③ Update road width, regenerate

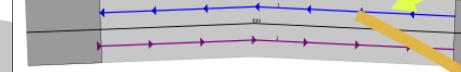
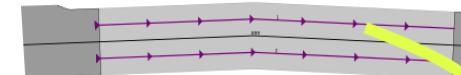
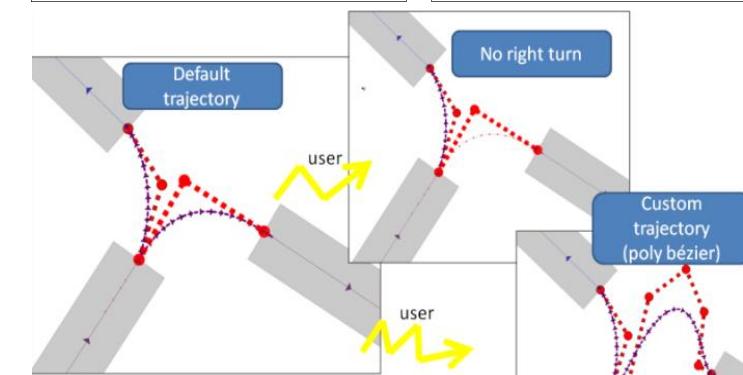
road surface

road axis

road width

Default trajectory

new road width

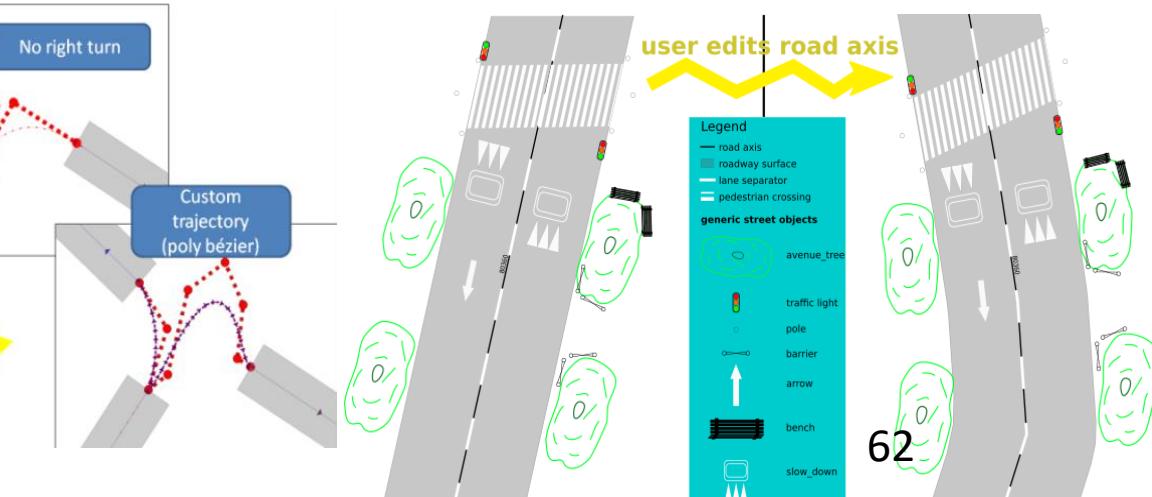
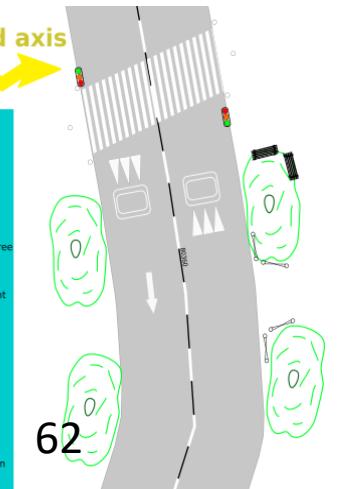


User overrides lane automatic direction :
UPSERT user input table. Geometry is still re-generated if necessary (default).

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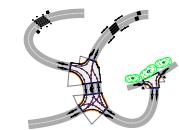
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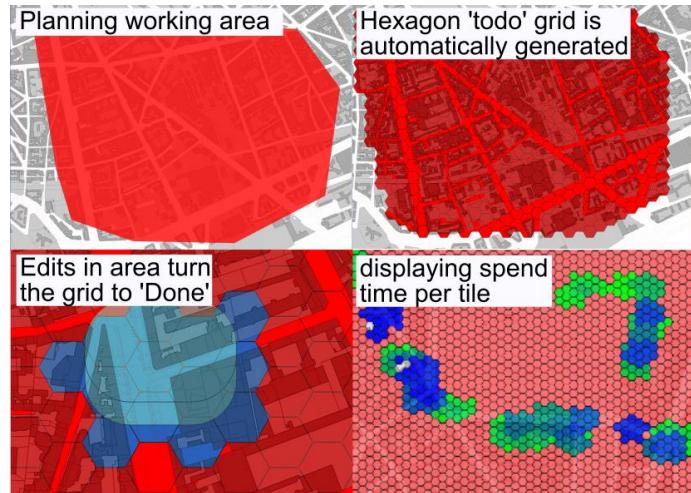
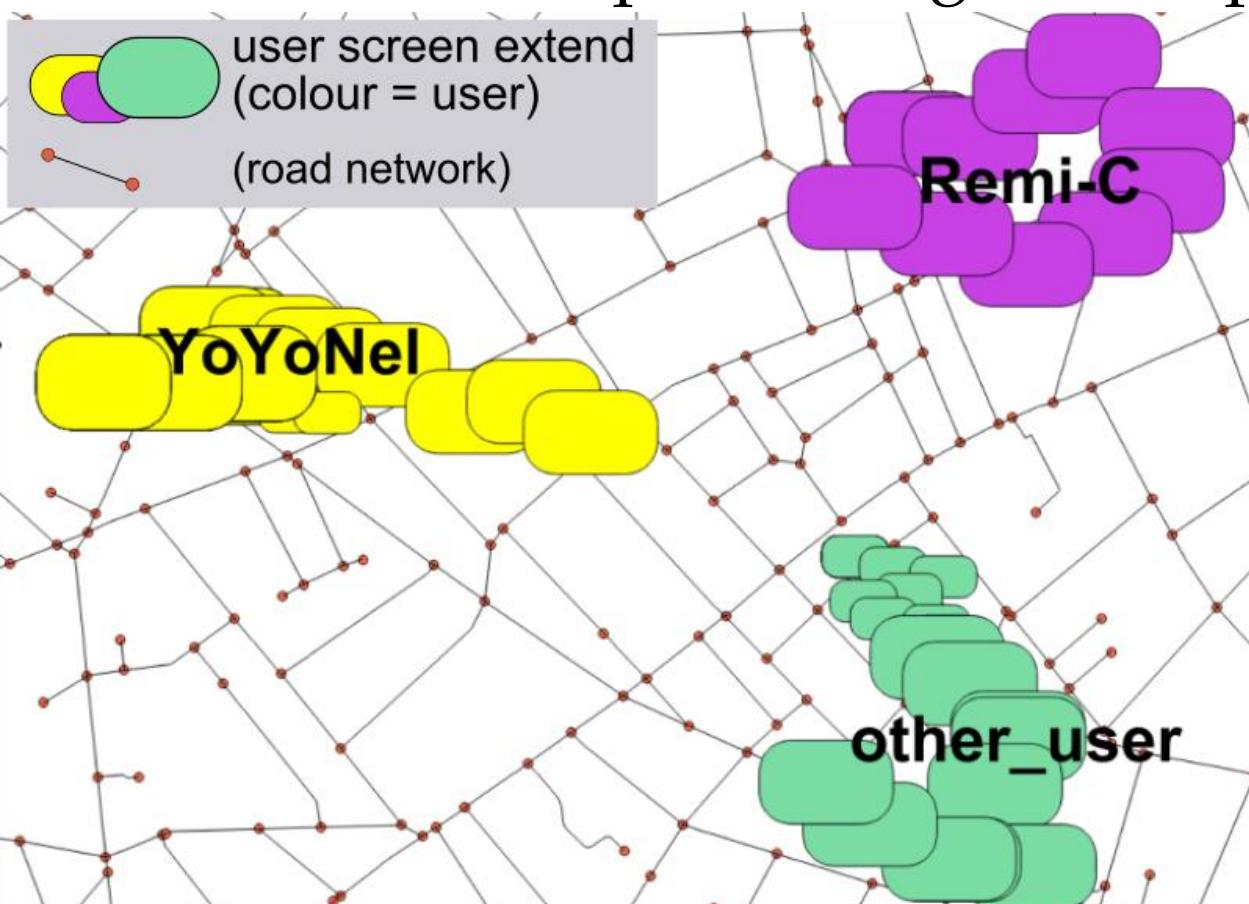
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- Multi-user editing can be facilitated
- “Interactive Map Tracking” QGIS plugin with Lionel Atty



StreetGen : street objects

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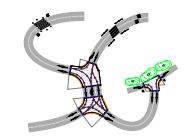
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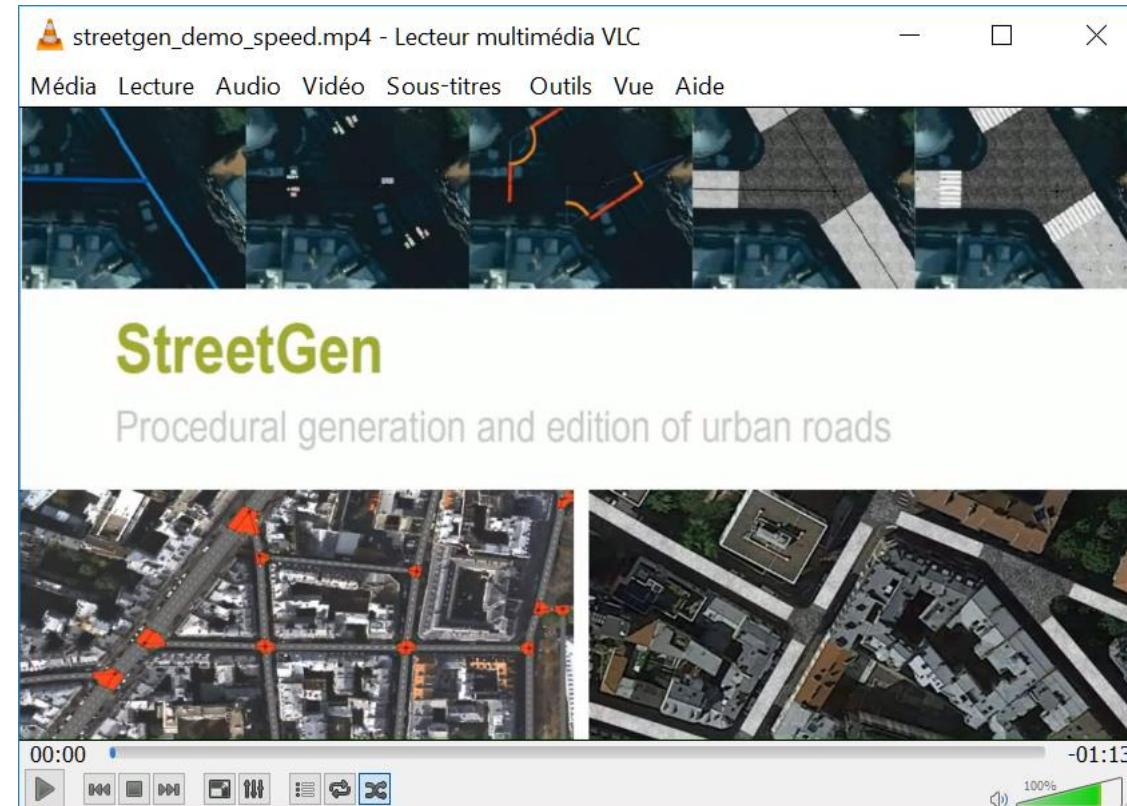
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- Results:
 - Interaction are fast enough to be interactive



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

StreetGen : street objects

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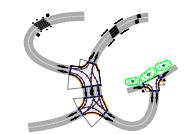
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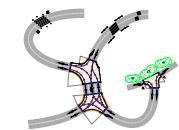


- Contributions

- New interaction paradigm
- Works with any mapping framework
- Generic : design pattern to manage interactions and user input
- Concept of geometric interactors

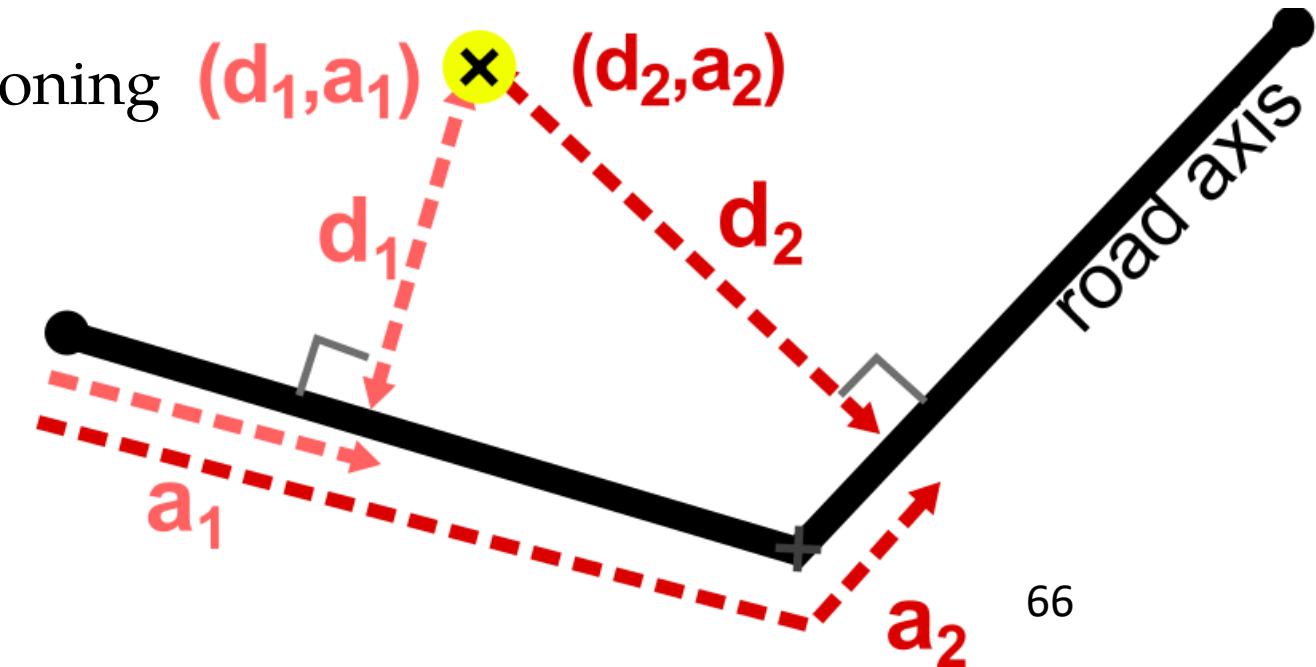
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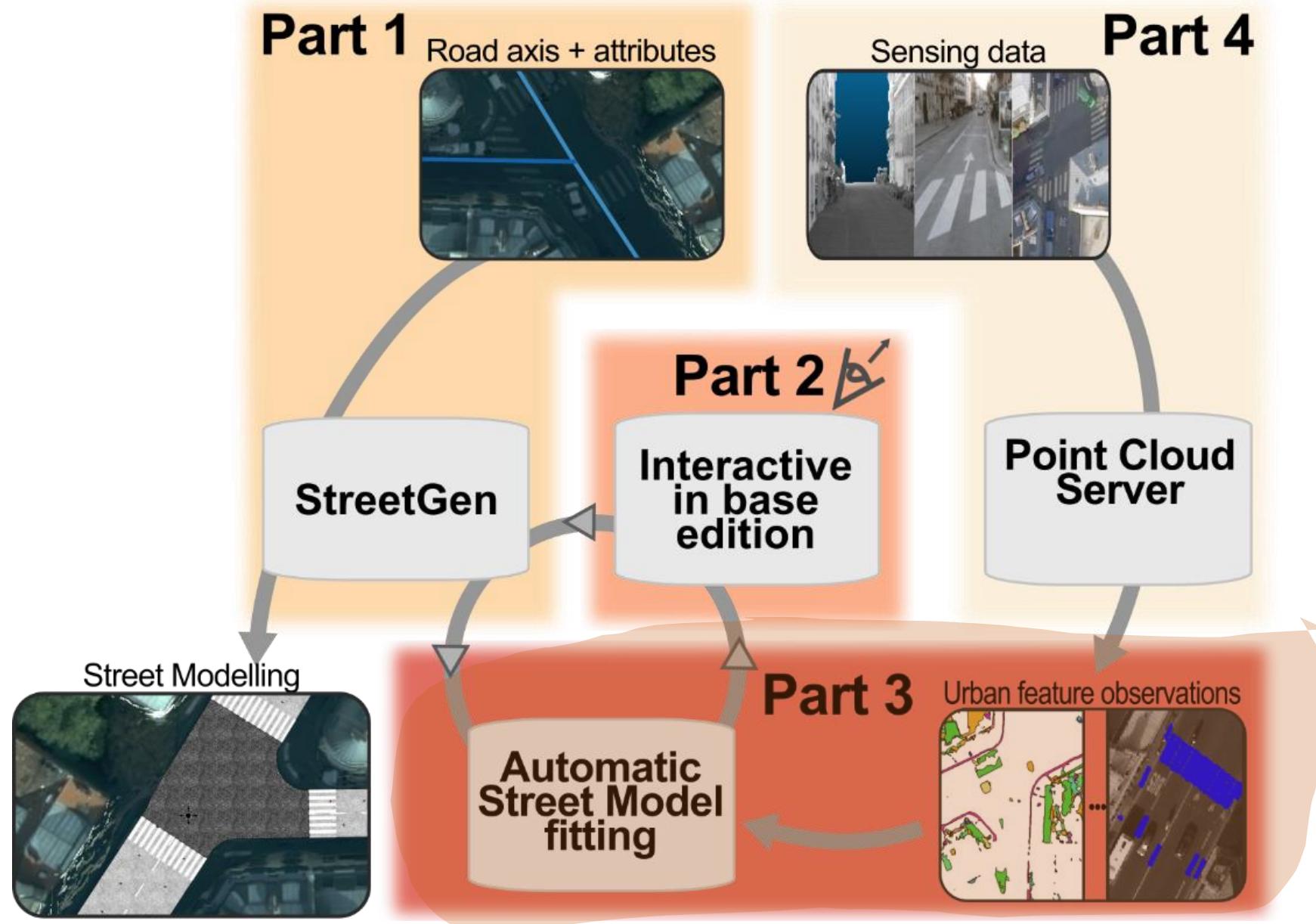


- Several Limitations

- limited to straightforward interaction
(guessing user action is easy)
- Old school : Hard to develop/test/maintain
- one transaction → should be short
- Objects: relative positioning
may be ambiguous



Abstract



width= 8; lane= 3

width= 6; lane= 2

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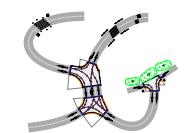
Conclusion

width= 4; lane= 1

Automating street modelling

Inverse procedural modelling concept

Fitting model to real streets



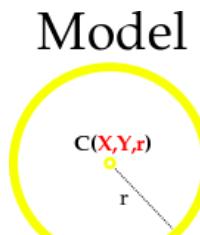
StreetGen : Inverse procedural modelling

width= 8; lane= 3

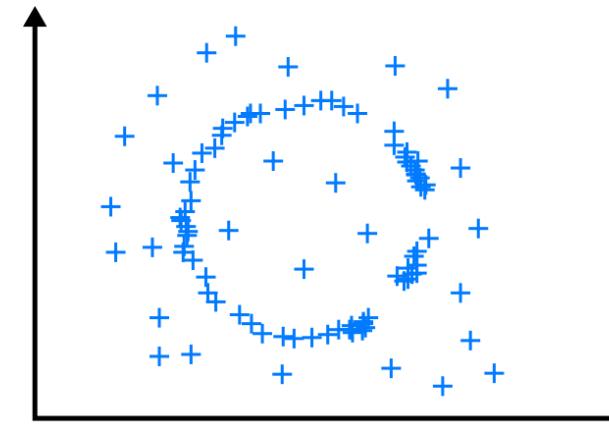
width= 6; lane= 2

Inverse Problem:

width= 4; lane= 1

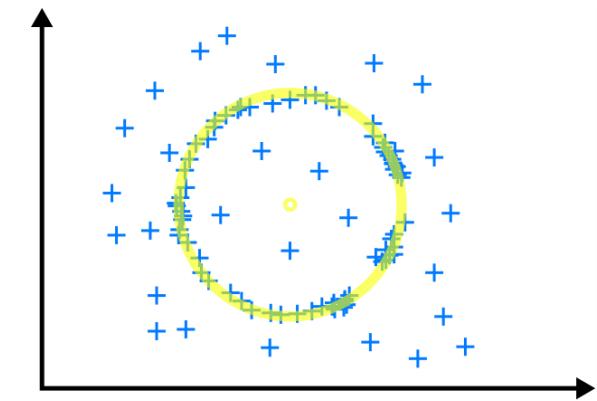


+



fit
→

Model = C(3.2,2.1,1.5)



Procedural model

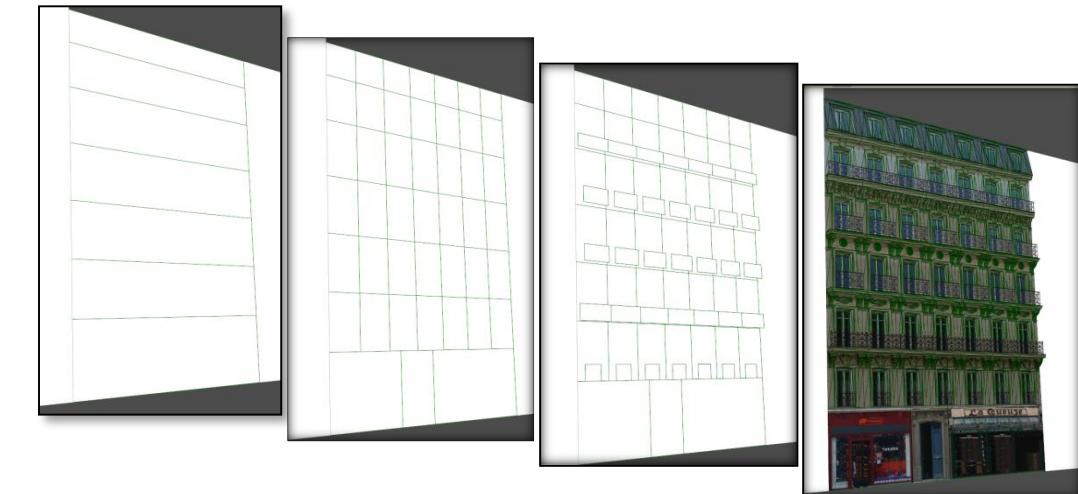
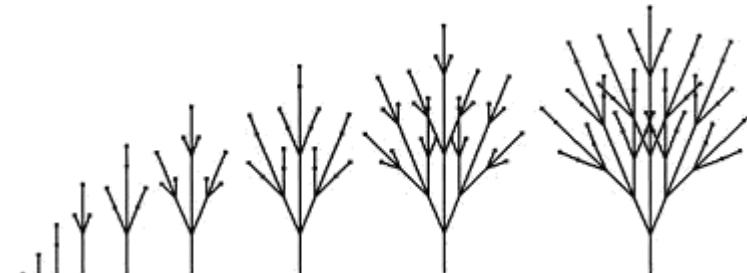
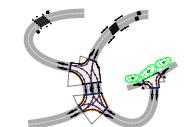


Image : Three-dimensional modelling and visualisation of vegetation for landscape simulation



StreetGen : Inverse procedural modelling

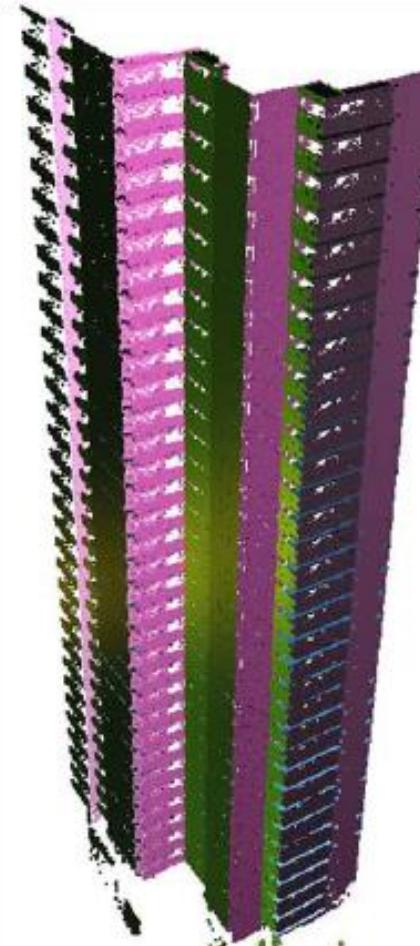
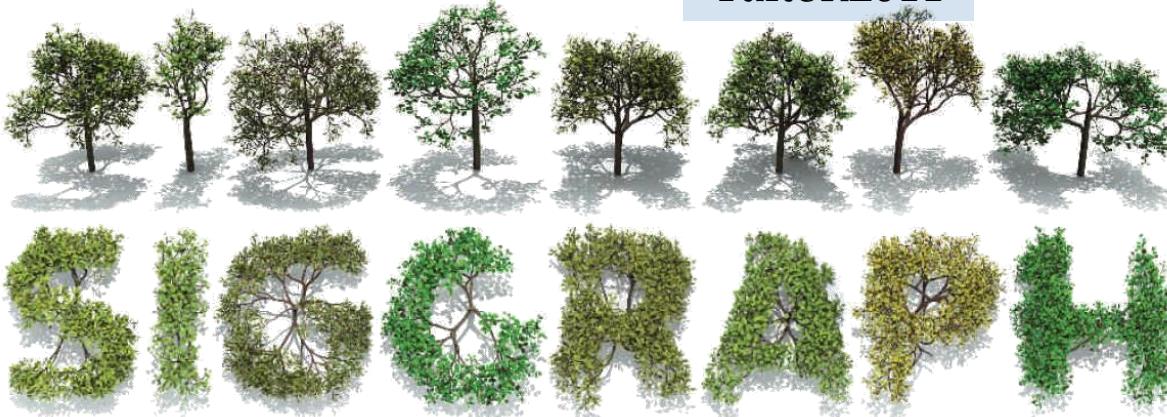
width= 8; lane= 3

width= 6; lane= 2

Fit a generic
procedural model to a
specific situation

Specific situation?
→ We need data!

Talton2011



Wan2012



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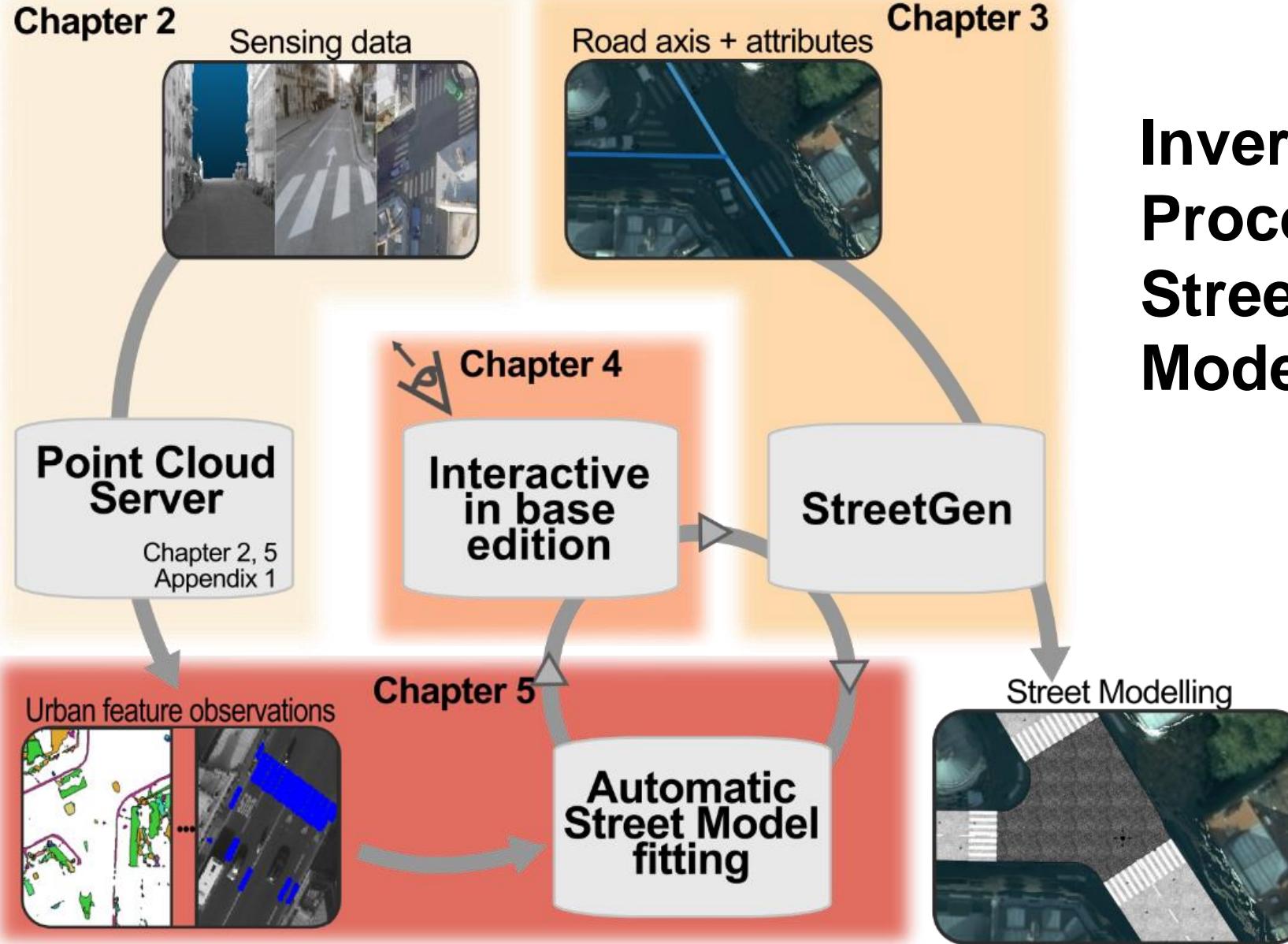
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Abstract



Inverse Procedural Street Modelling

StreetGen : Inverse procedural modelling

width= 8; lane= 3

width= 6; lane= 2

width= 4; lane= 1

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- What type of data for streets?

- Precise
- Good coverage
- Frequent

- Aerial image?

- Good coverage
- Low 3D precision



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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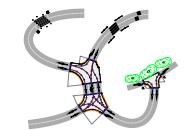
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width= 4; lane= 1



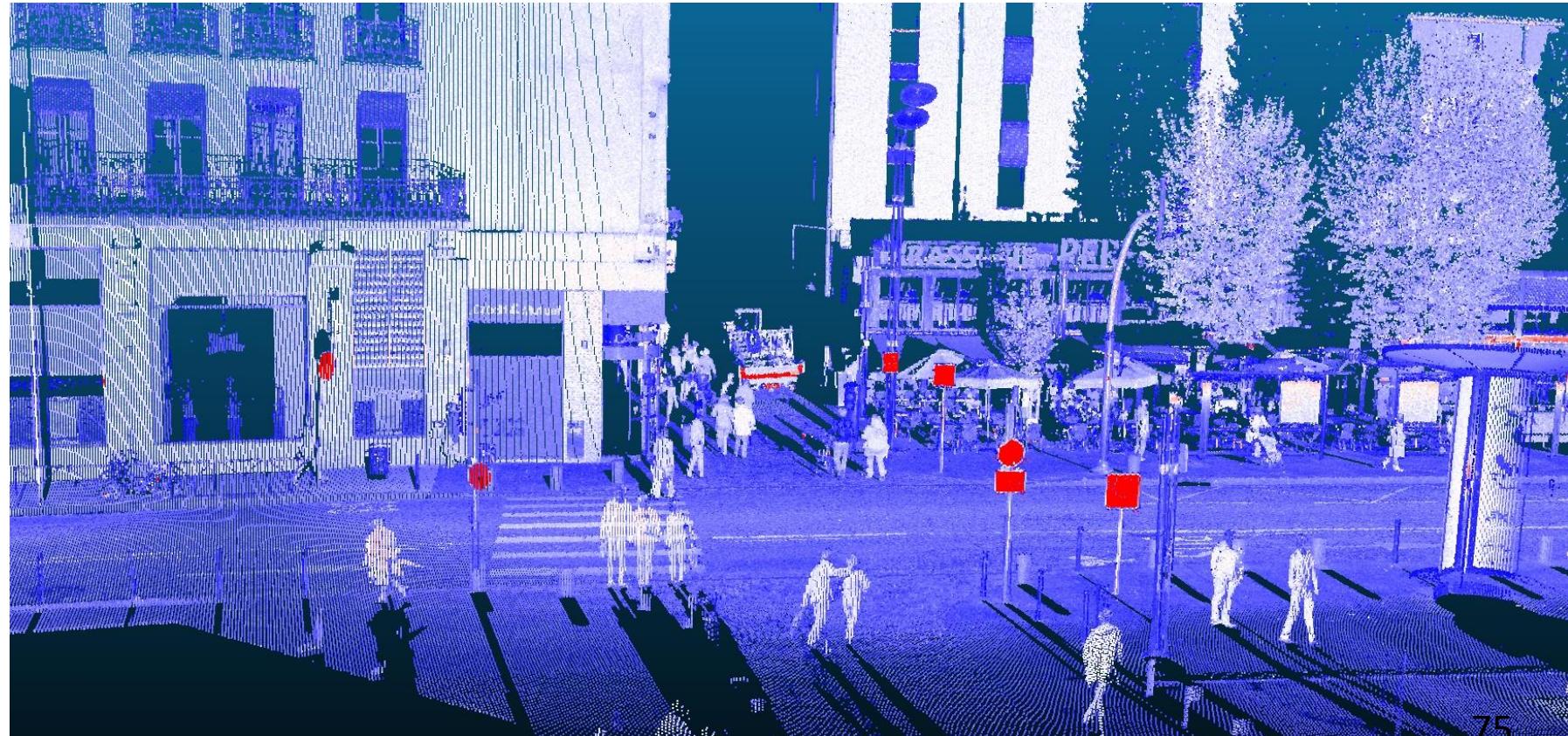
StreetGen : Inverse procedural modelling

width= 8; lane= 3

width= 6; lane= 2

Lidar: 3D point clouds

- precise 3D



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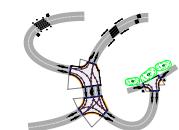
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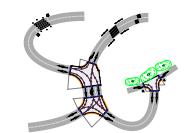


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Inverse Procedural modelling: method

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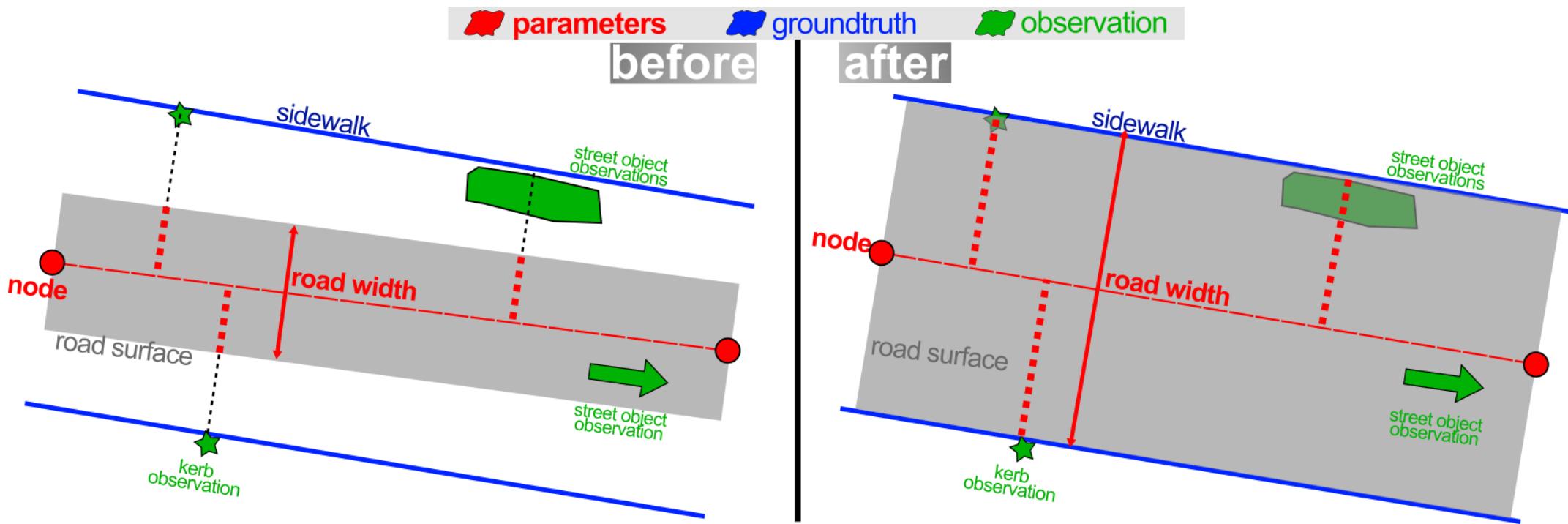
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- Initial road model + observation → optimisation → fit road model



Inverse Procedural modelling: method

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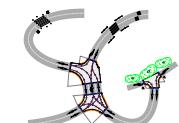
Streets

Interaction

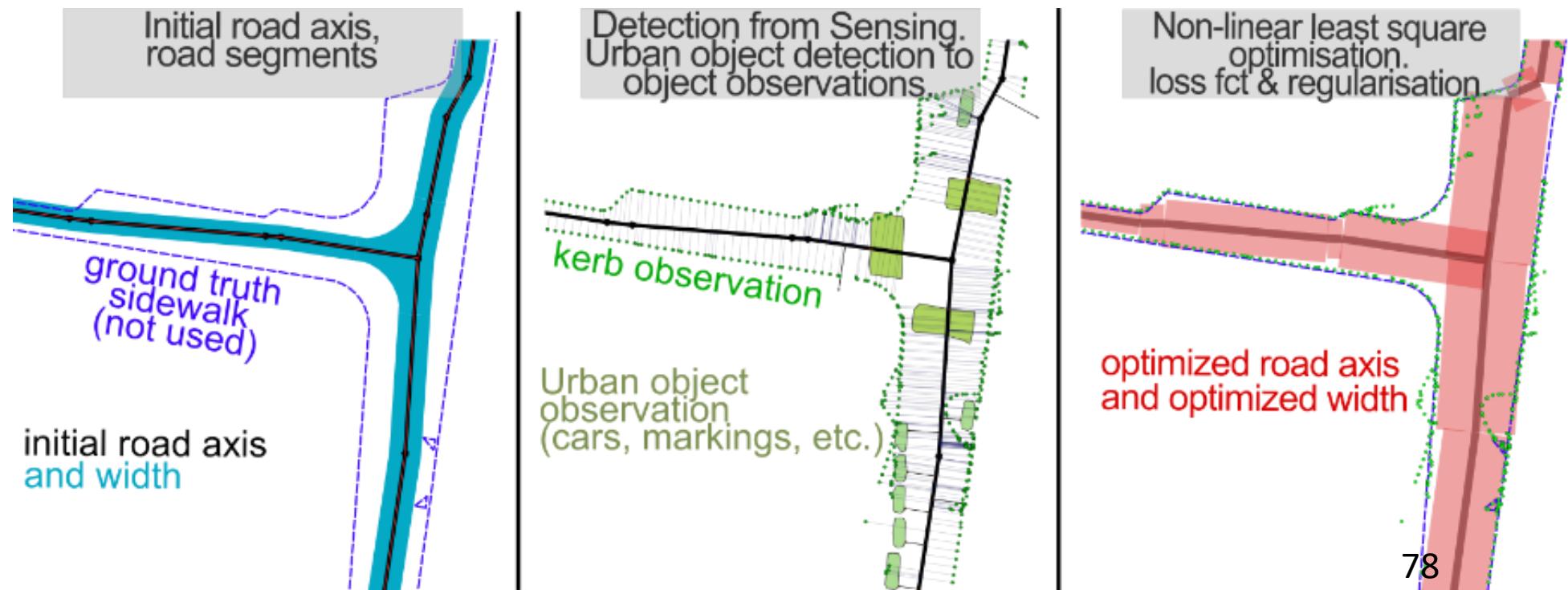
Automation

P.C. Server

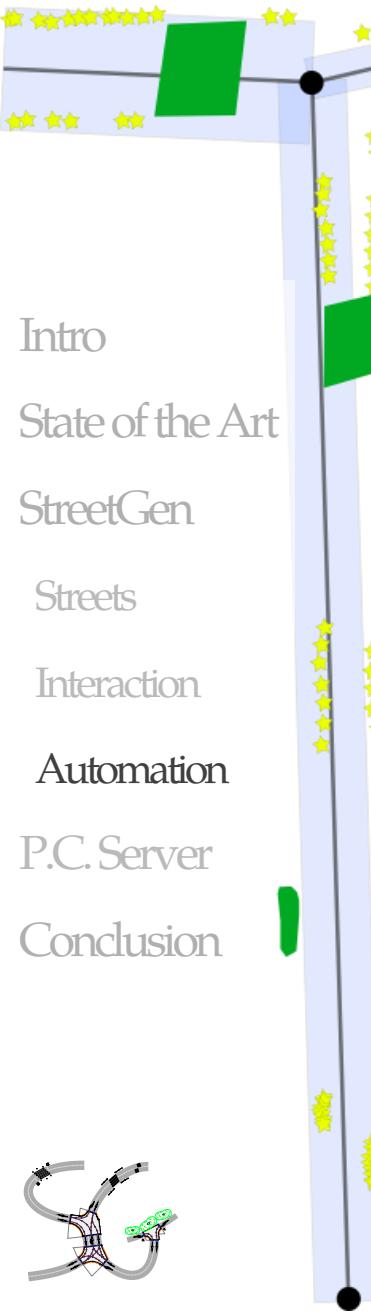
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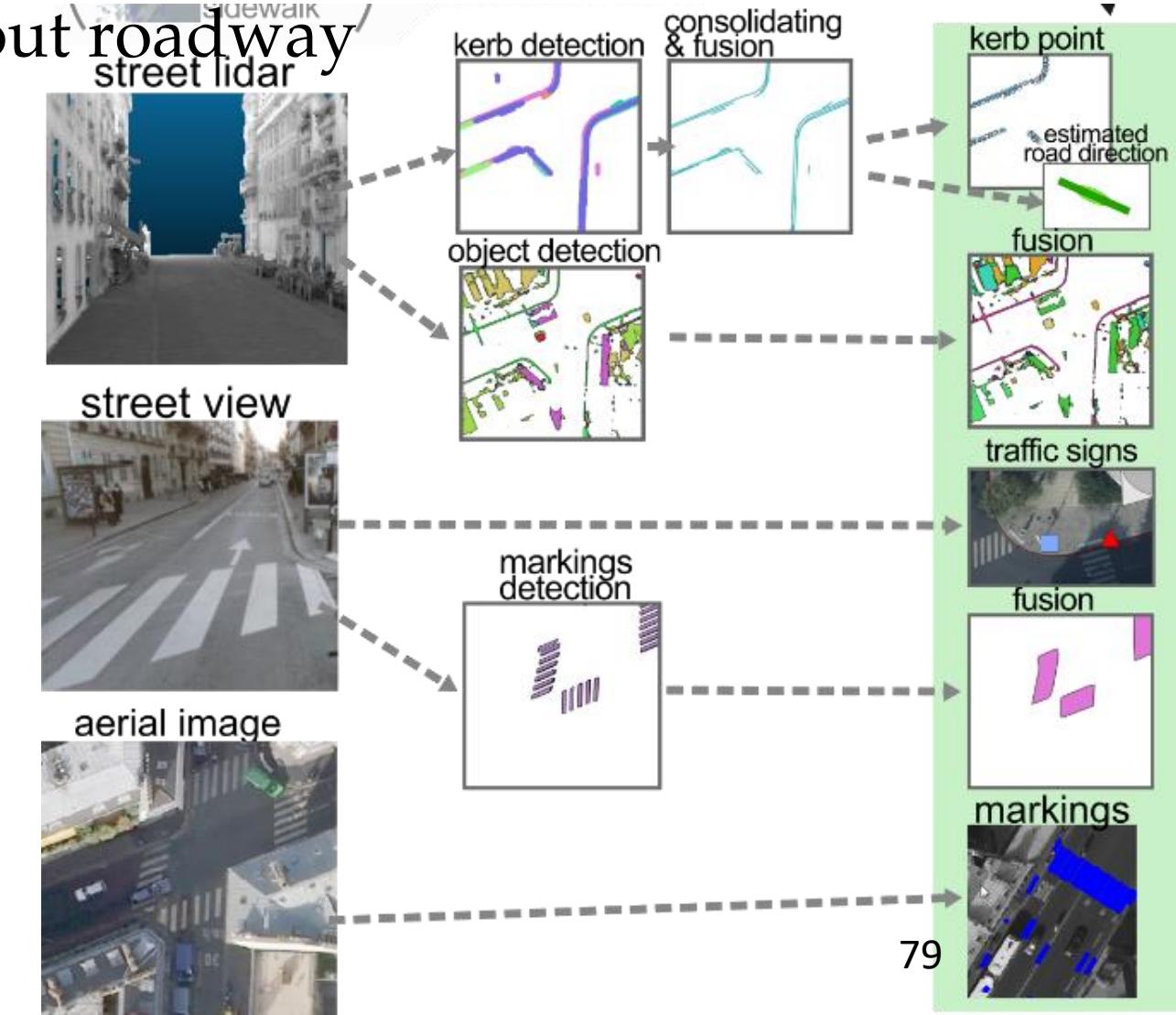
- Initial road model + observation → observation affects part of road model → fit road model
- Mecanical Analogy : observations pull/push road model= forces



Inverse Procedural modelling: observations



- Observation = clues about roadway



Inverse Procedural modelling: observations

- Observation = clues about roadway

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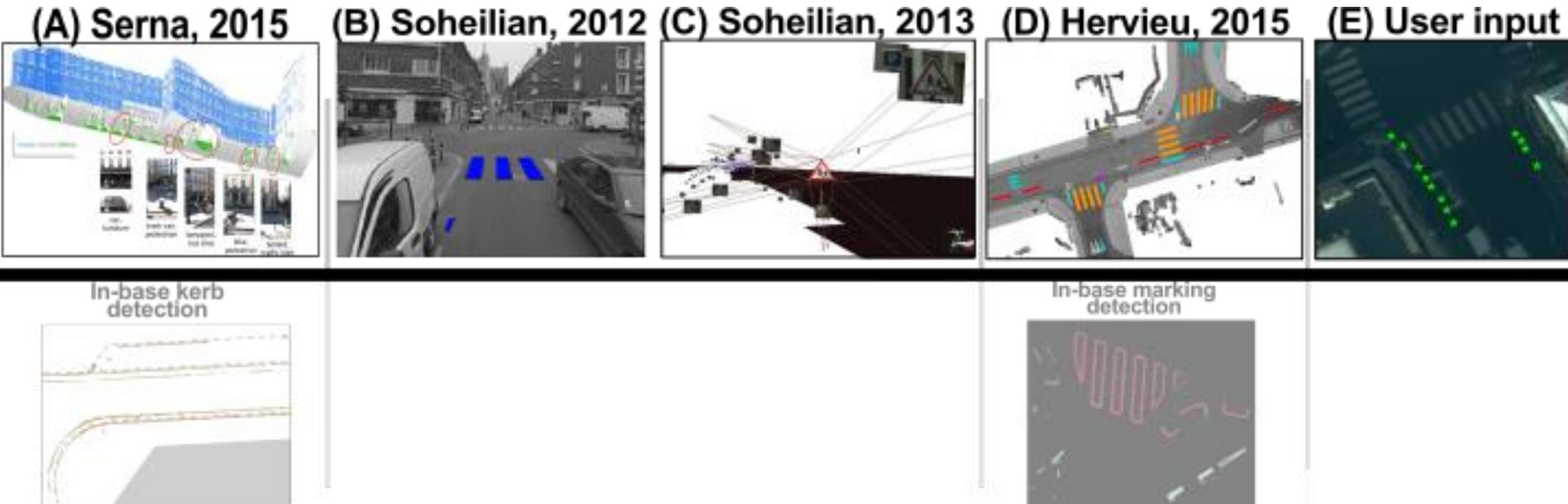
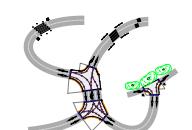
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Inverse Procedural modelling: forces

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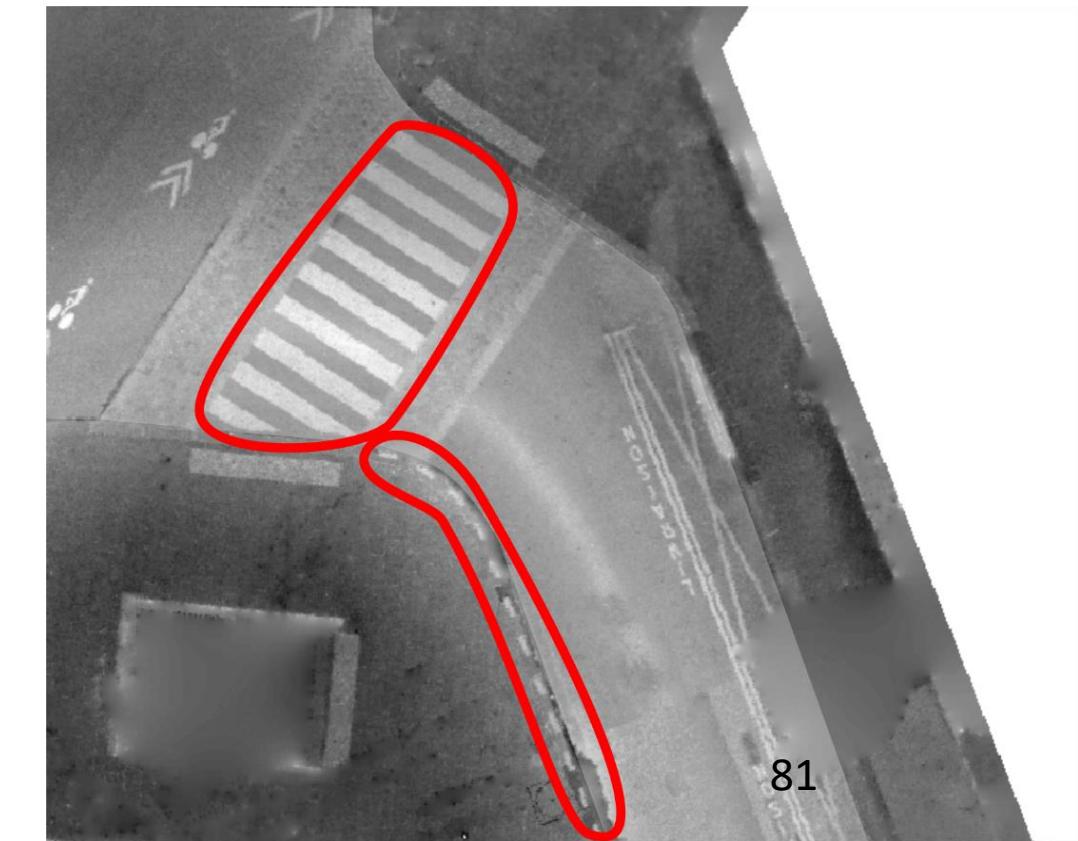
Automation

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Conclusion



- Each street object type has an expected position:
 - IN/OUT + BORDER_IN/BORDER_OUT (dist)
- Ex :
 - Pedestrian crossing marking : BORDER_IN (0.2 m)
 - No parking markings : BORDER_OUT (0.1m)
 - road markings : IN
 - ...



Inverse Procedural modelling: forces

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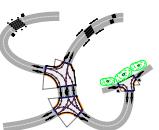
Streets

Interaction

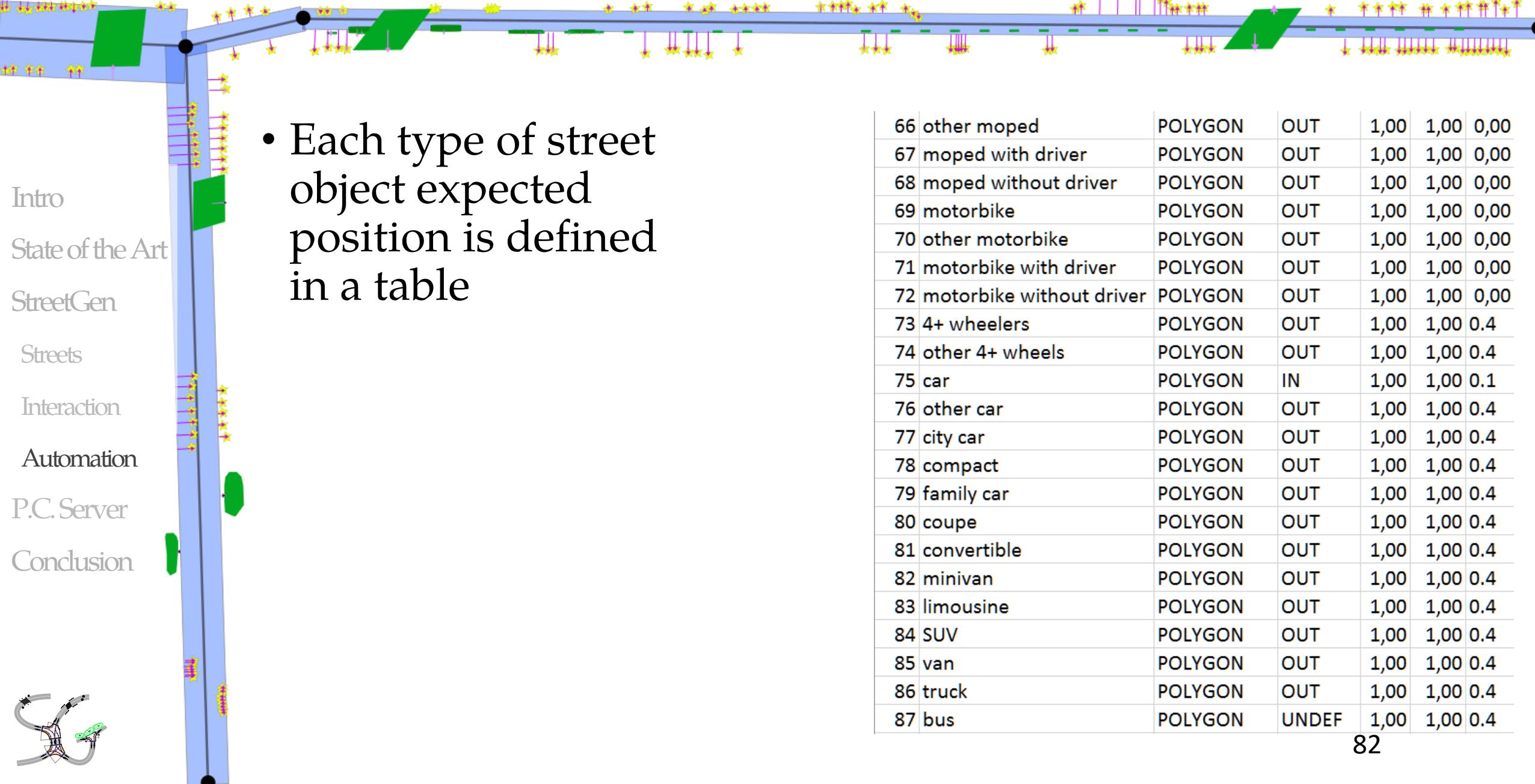
Automation

P.C. Server

Conclusion



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



66 other moped	POLYGON	OUT	1,00	1,00	0,00
67 moped with driver	POLYGON	OUT	1,00	1,00	0,00
68 moped without driver	POLYGON	OUT	1,00	1,00	0,00
69 motorbike	POLYGON	OUT	1,00	1,00	0,00
70 other motorbike	POLYGON	OUT	1,00	1,00	0,00
71 motorbike with driver	POLYGON	OUT	1,00	1,00	0,00
72 motorbike without driver	POLYGON	OUT	1,00	1,00	0,00
73 4+ wheelers	POLYGON	OUT	1,00	1,00	0,4
74 other 4+ wheels	POLYGON	OUT	1,00	1,00	0,4
75 car	POLYGON	IN	1,00	1,00	0,1
76 other car	POLYGON	OUT	1,00	1,00	0,4
77 city car	POLYGON	OUT	1,00	1,00	0,4
78 compact	POLYGON	OUT	1,00	1,00	0,4
79 family car	POLYGON	OUT	1,00	1,00	0,4
80 coupe	POLYGON	OUT	1,00	1,00	0,4
81 convertible	POLYGON	OUT	1,00	1,00	0,4
82 minivan	POLYGON	OUT	1,00	1,00	0,4
83 limousine	POLYGON	OUT	1,00	1,00	0,4
84 SUV	POLYGON	OUT	1,00	1,00	0,4
85 van	POLYGON	OUT	1,00	1,00	0,4
86 truck	POLYGON	OUT	1,00	1,00	0,4
87 bus	POLYGON	UNDEF	1,00	1,00	0,4

Inverse Procedural modelling: forces

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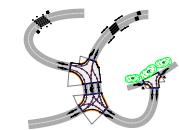
Streets

Interaction

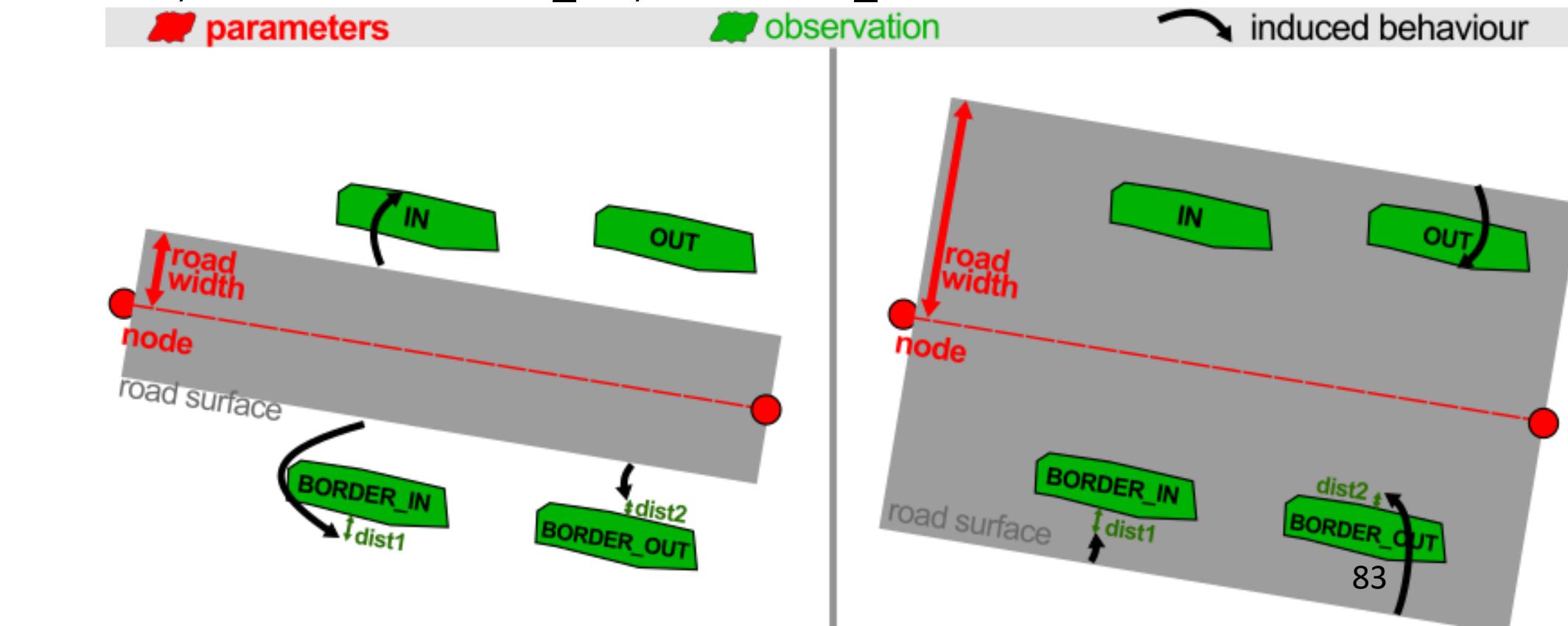
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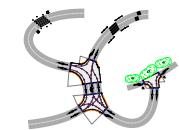


- Observations generate forces on road axis/width
- Each street object type has an expected position:
 - IN/OUT + BORDER_IN/BORDER_OUT + dist

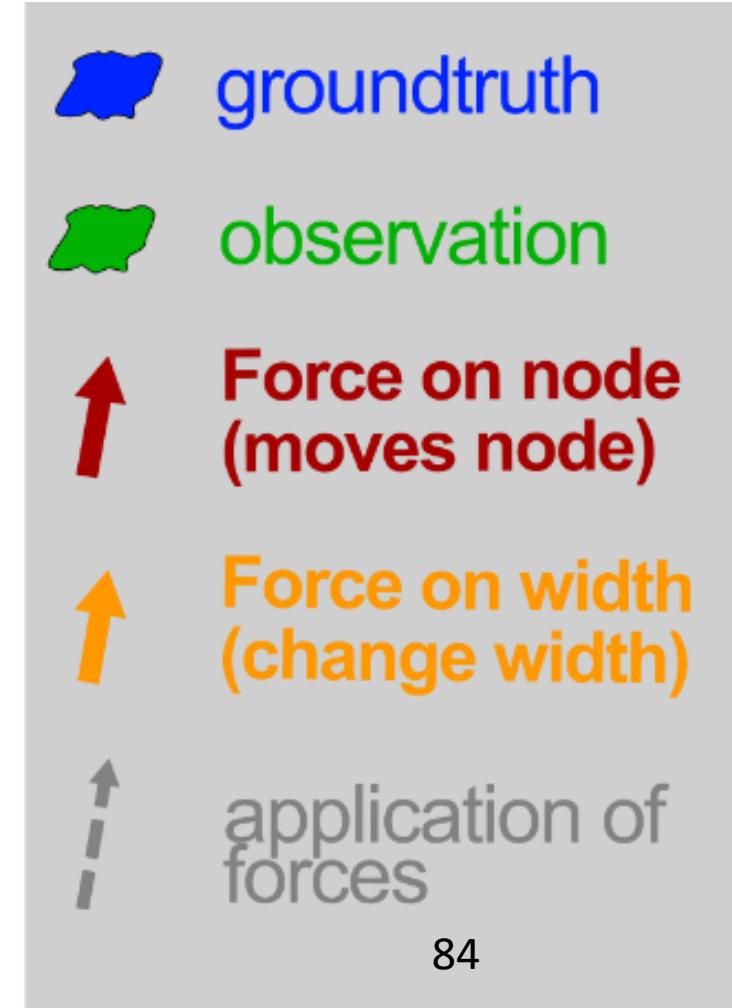
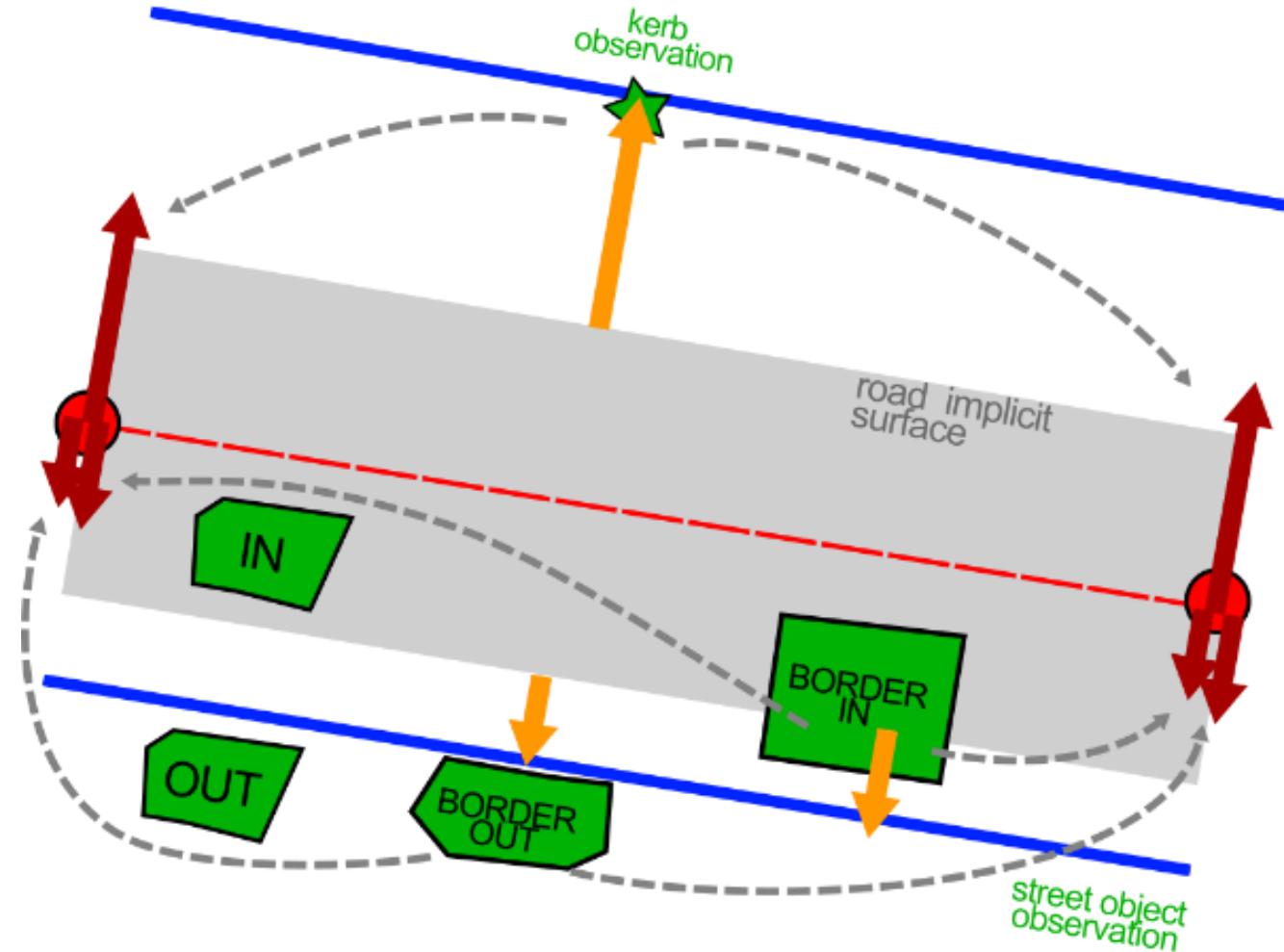


Inverse Procedural modelling: forces

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- So if we sum up forces from observations :



Inverse Procedural modelling: forces

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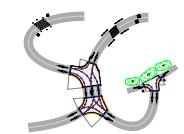
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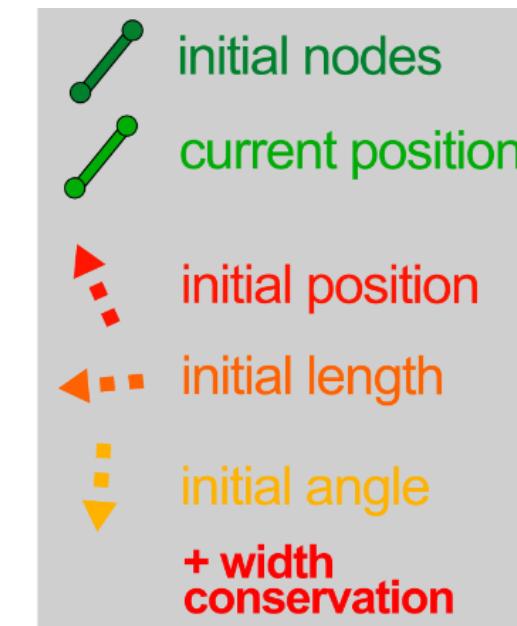
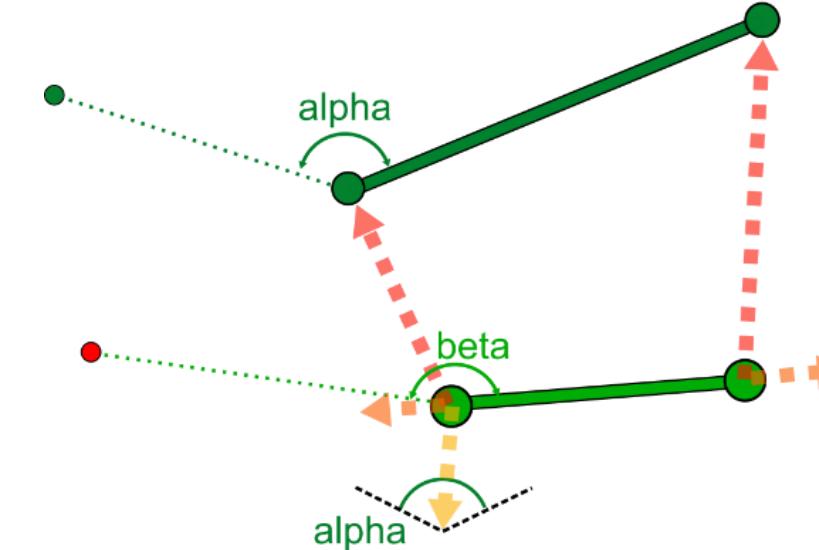
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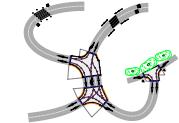


- Others forces: resisting changes : express confidence in initial road model

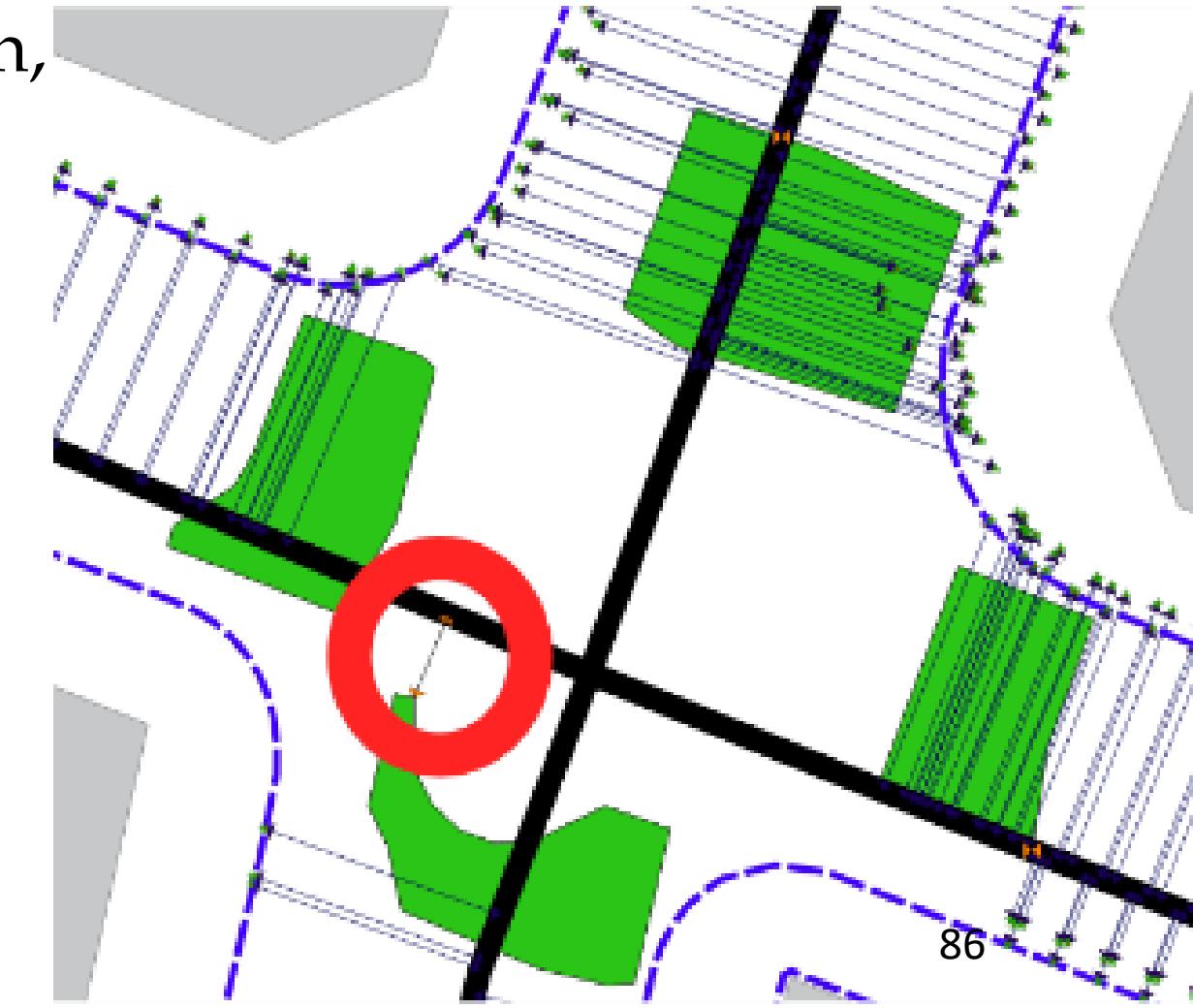


Inverse Procedural modelling : matching

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



Inverse Procedural modelling: matching

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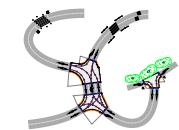
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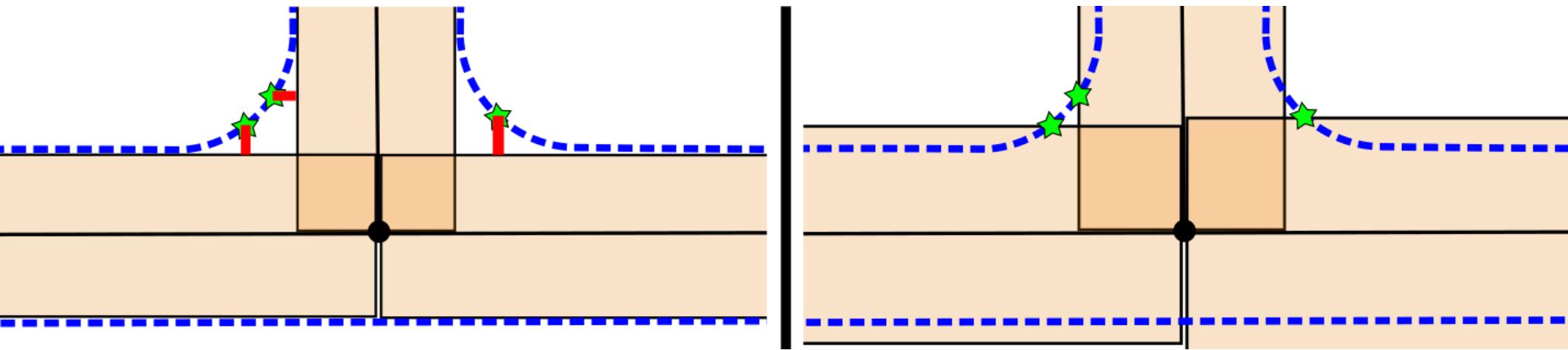
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- In intersection : can't use observations:
 - We would need to optimise full road surface model



Inverse Procedural modelling: experiment

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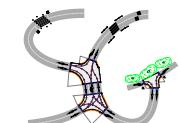
Streets

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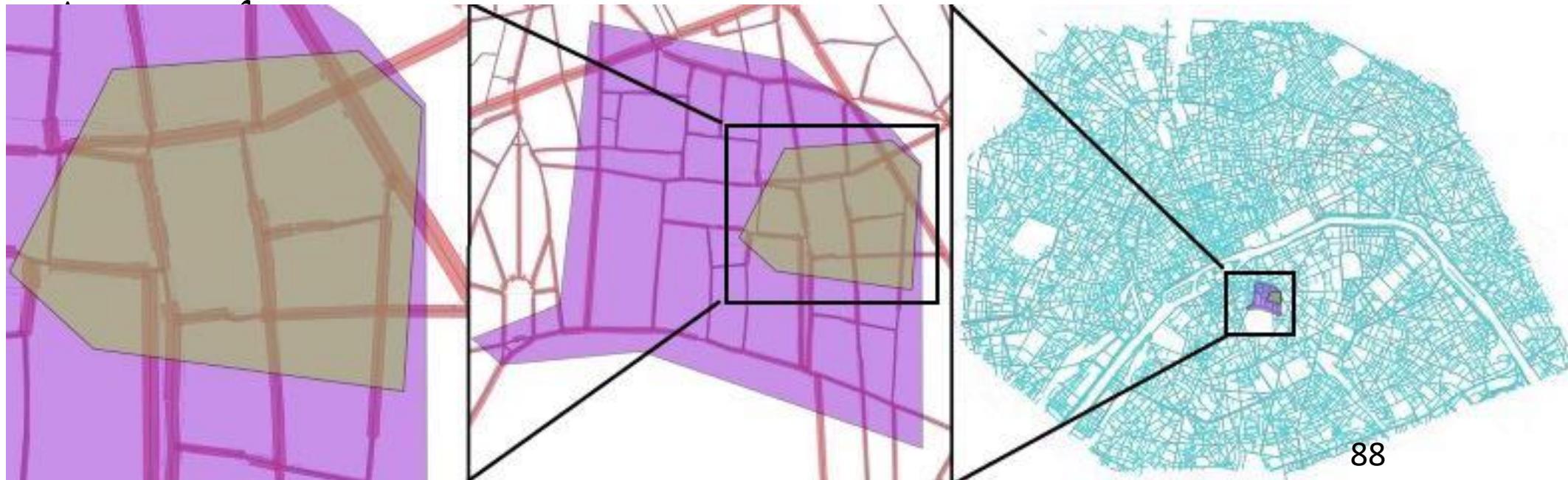
Automation

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Conclusion



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

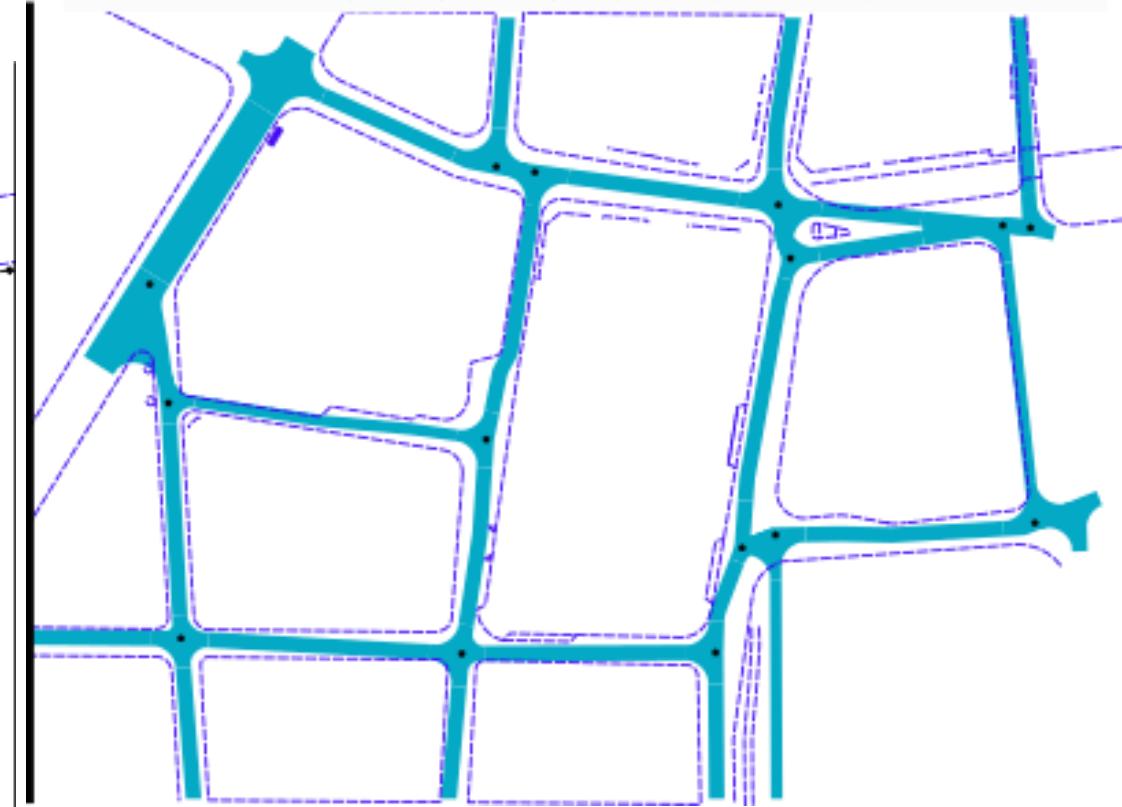


Inverse Procedural modelling : small area

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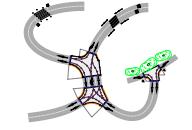


Initial axis and width



Inverse Procedural modelling : small area

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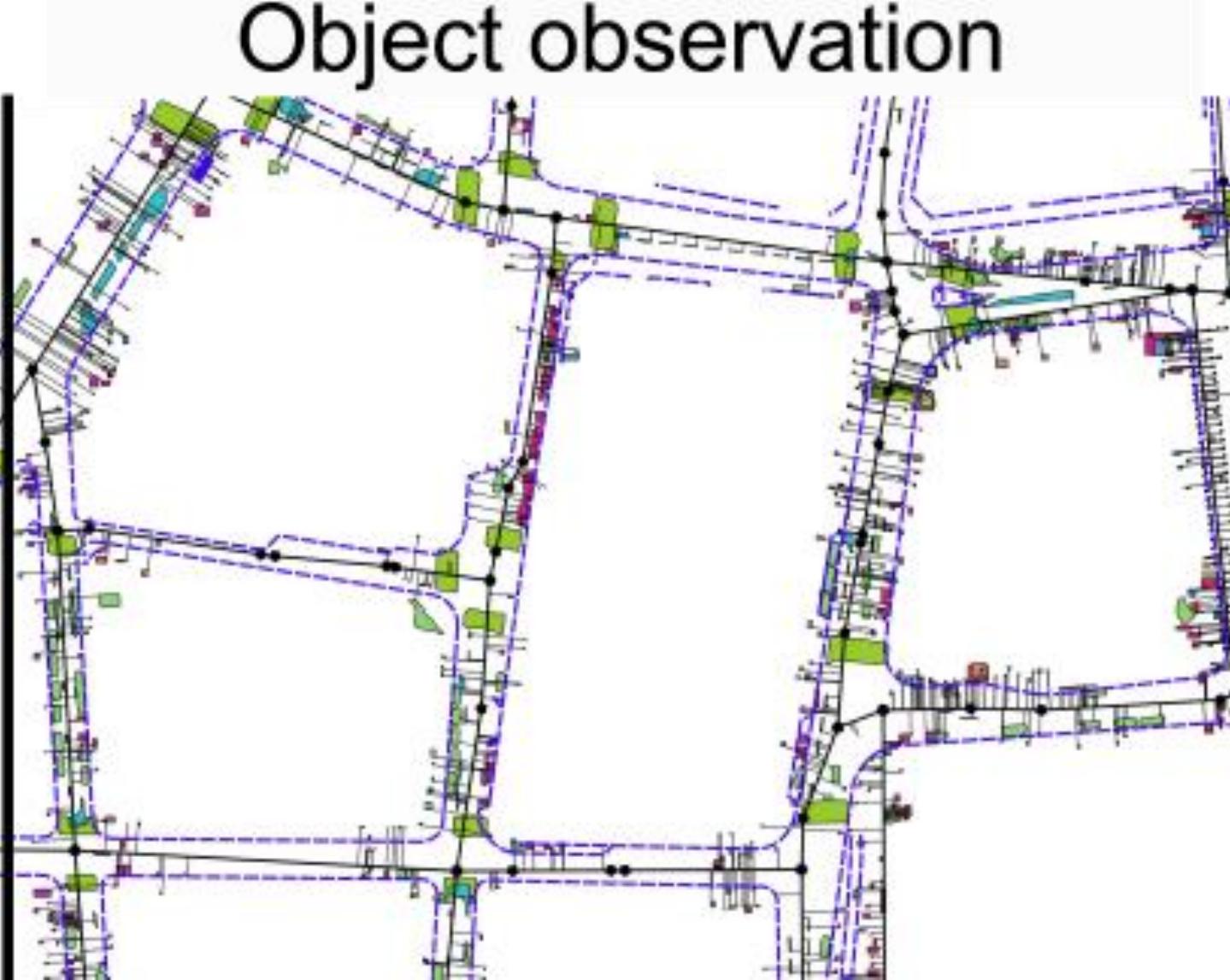
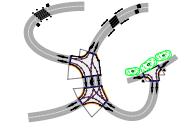


Kerb observation matching



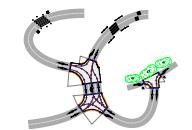
Inverse Procedural modelling : small area

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Inverse Procedural modelling : small area

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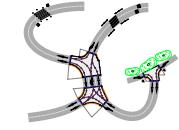


Using Kerb observation



Inverse Procedural modelling : small area

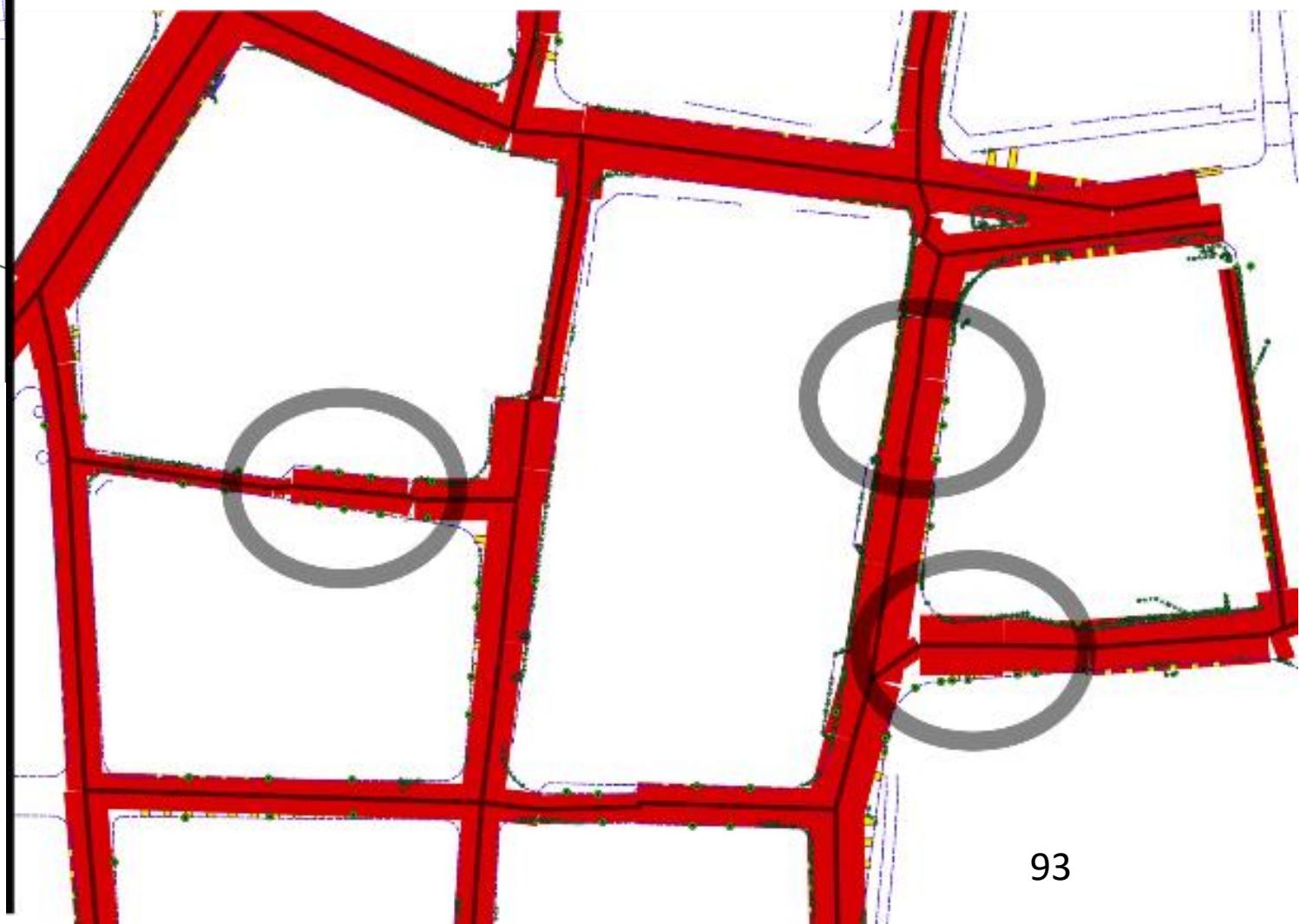
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User defines sidewalk points



Using Kerb and user input



Inverse Procedural modelling : small area

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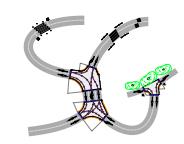
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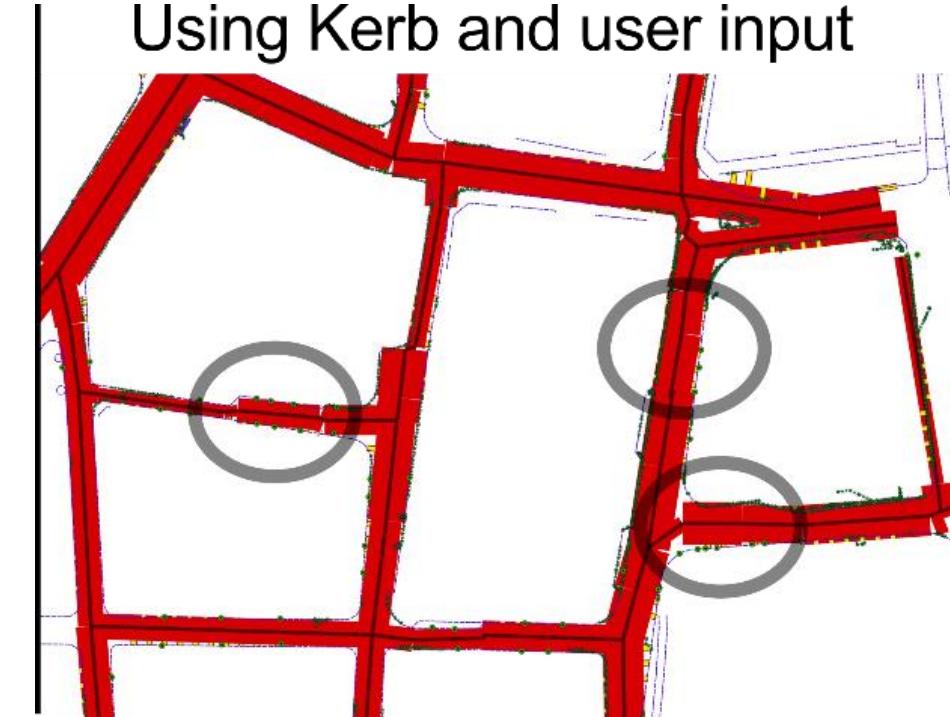
Conclusion



- Quantitative evaluation:
- Using Only kerb observation:
 - Median dist to Open Data Paris :
 - **from 1.8m → 0.4m** (with user input: **0.34m**)

It's much better, robust and fast (50ms)!

Using Kerb and user input



Inverse Procedural modelling : sensing area

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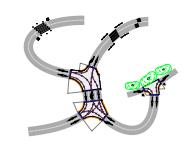
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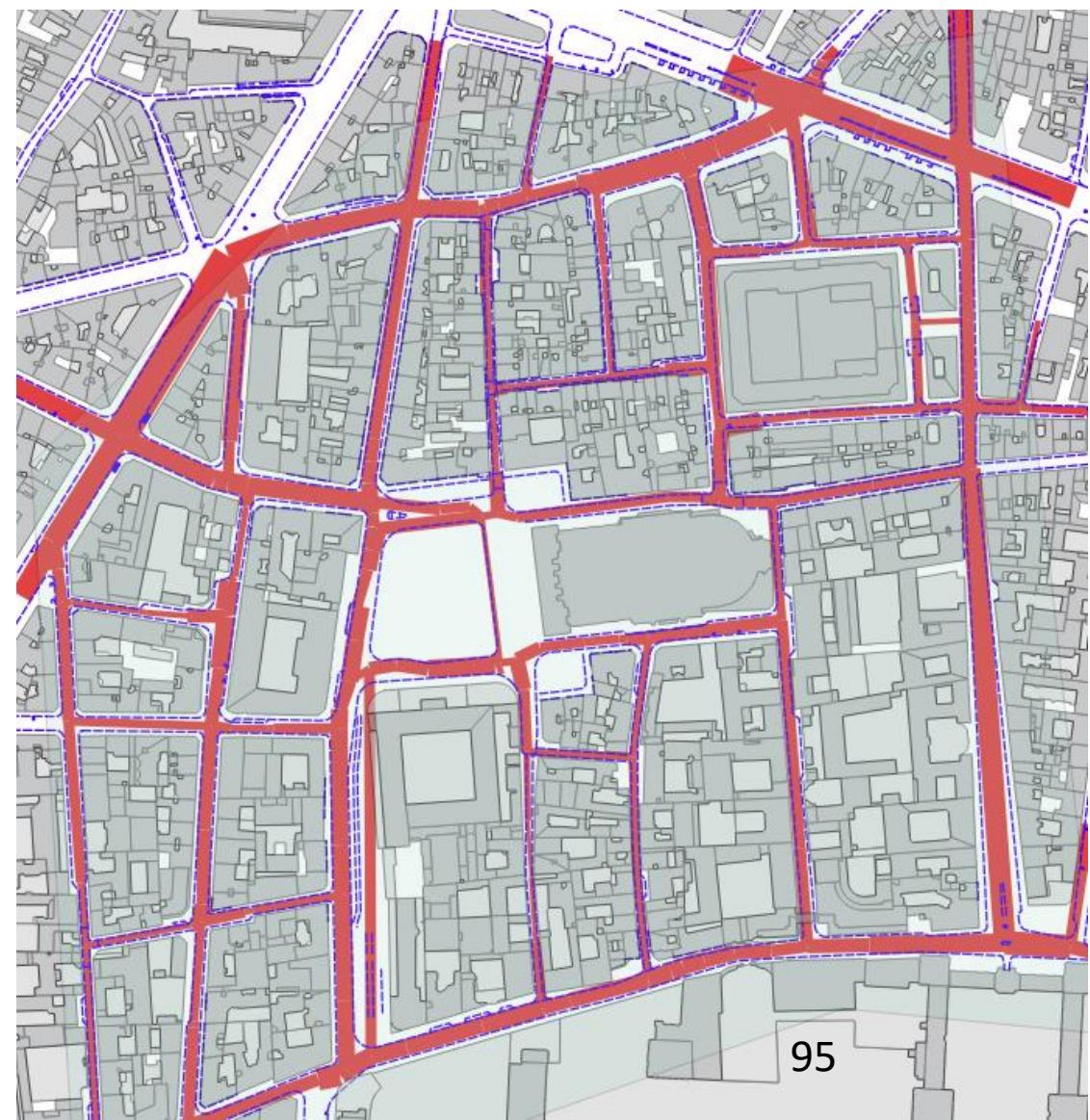
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- Whole sensing area:
Results:
Looks ok, but,



Inverse Procedural modelling : sensing area

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- Yellow circle are proportional to error:
- Most of the cases :
 - **Not enough observations!**
- Yet, Median dist to ODParis : from **1.5m → 0.6m**
- → it's still way better



Inverse Procedural modelling : Paris area

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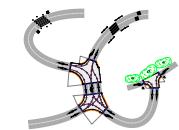
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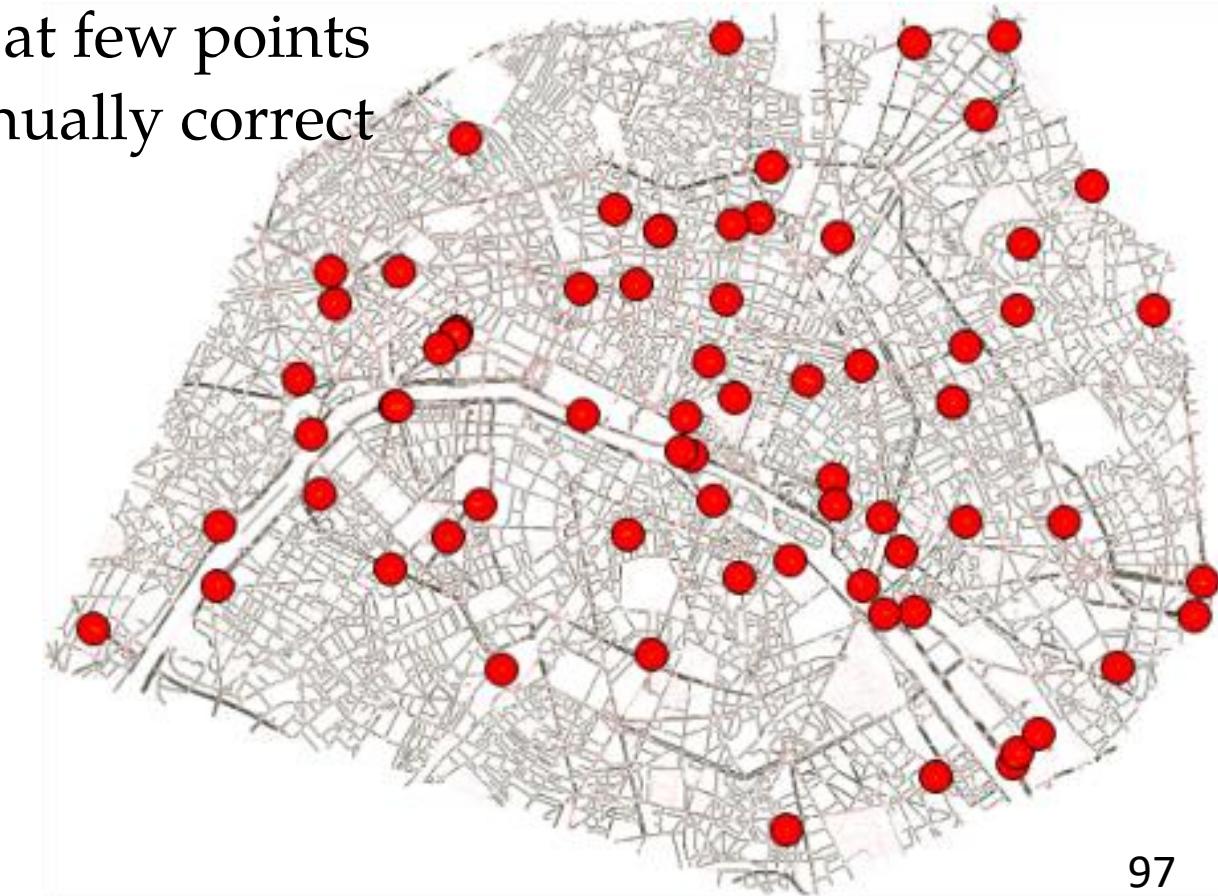
Automation

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- Whole Paris with Open Data Paris (Ideal data) : works but :
 - topology is broken at few points
 - Few enough to manually correct
 - from 1.5m → 0.1m



Inverse Procedural modelling: Streetgen on optim

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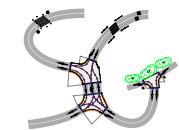
Streets

Interaction

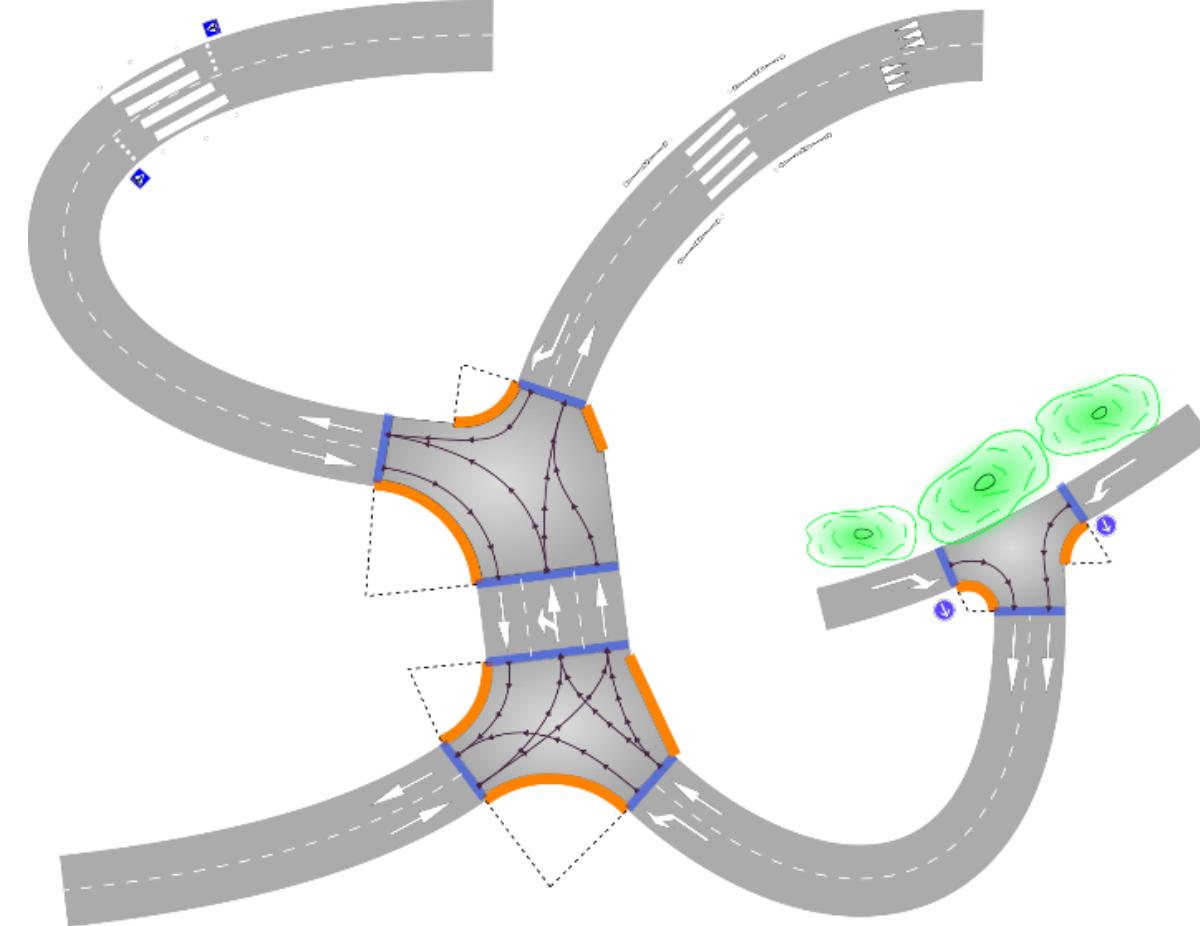
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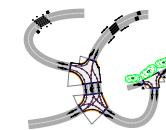


- Once simple road model is optimised,
we can generate streets with StreetGen

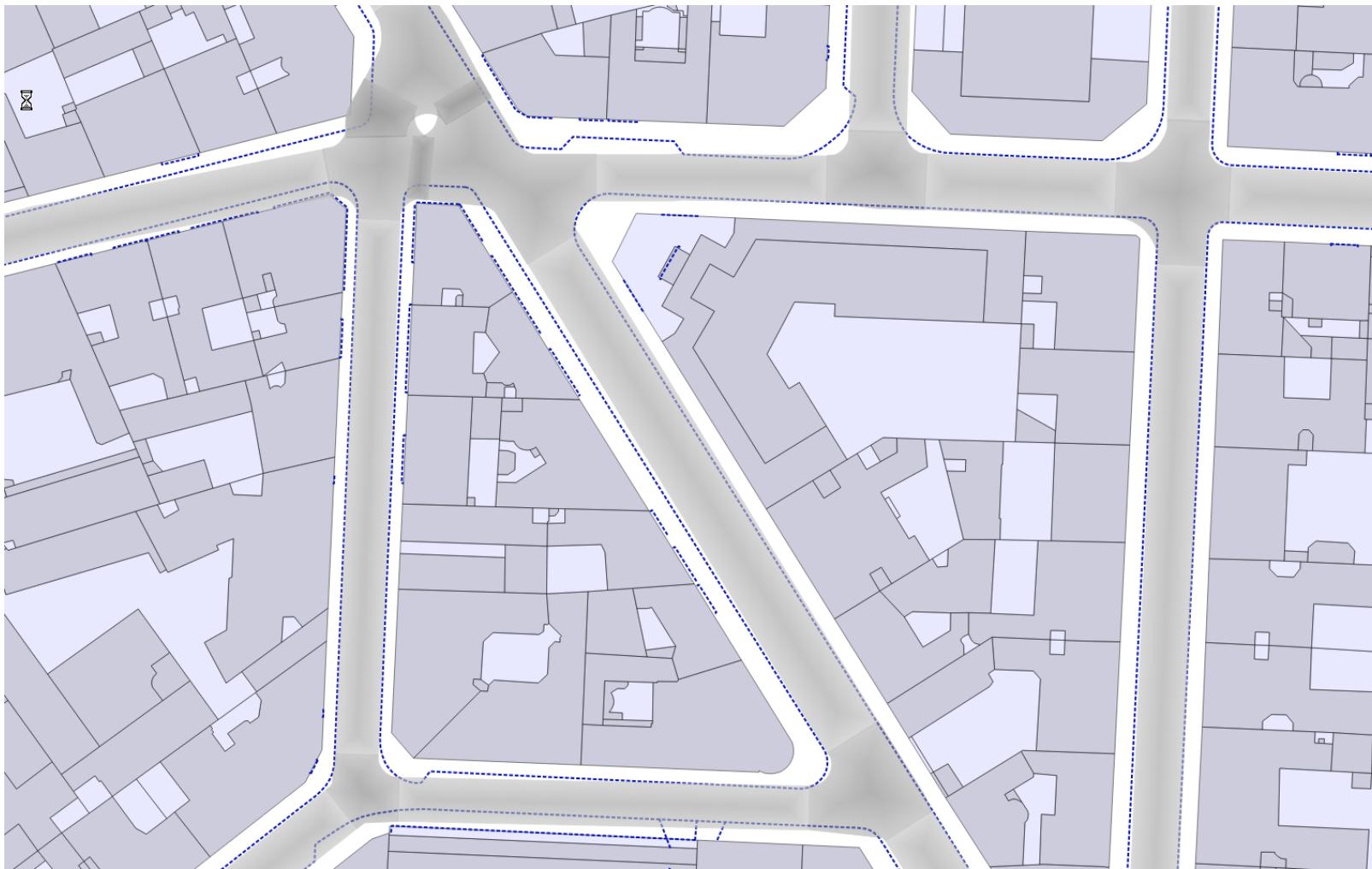


Inverse Procedural modelling: Streetgen on optim

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- Streetgen after optimisation



Inverse Procedural modelling: Streetgen on optim

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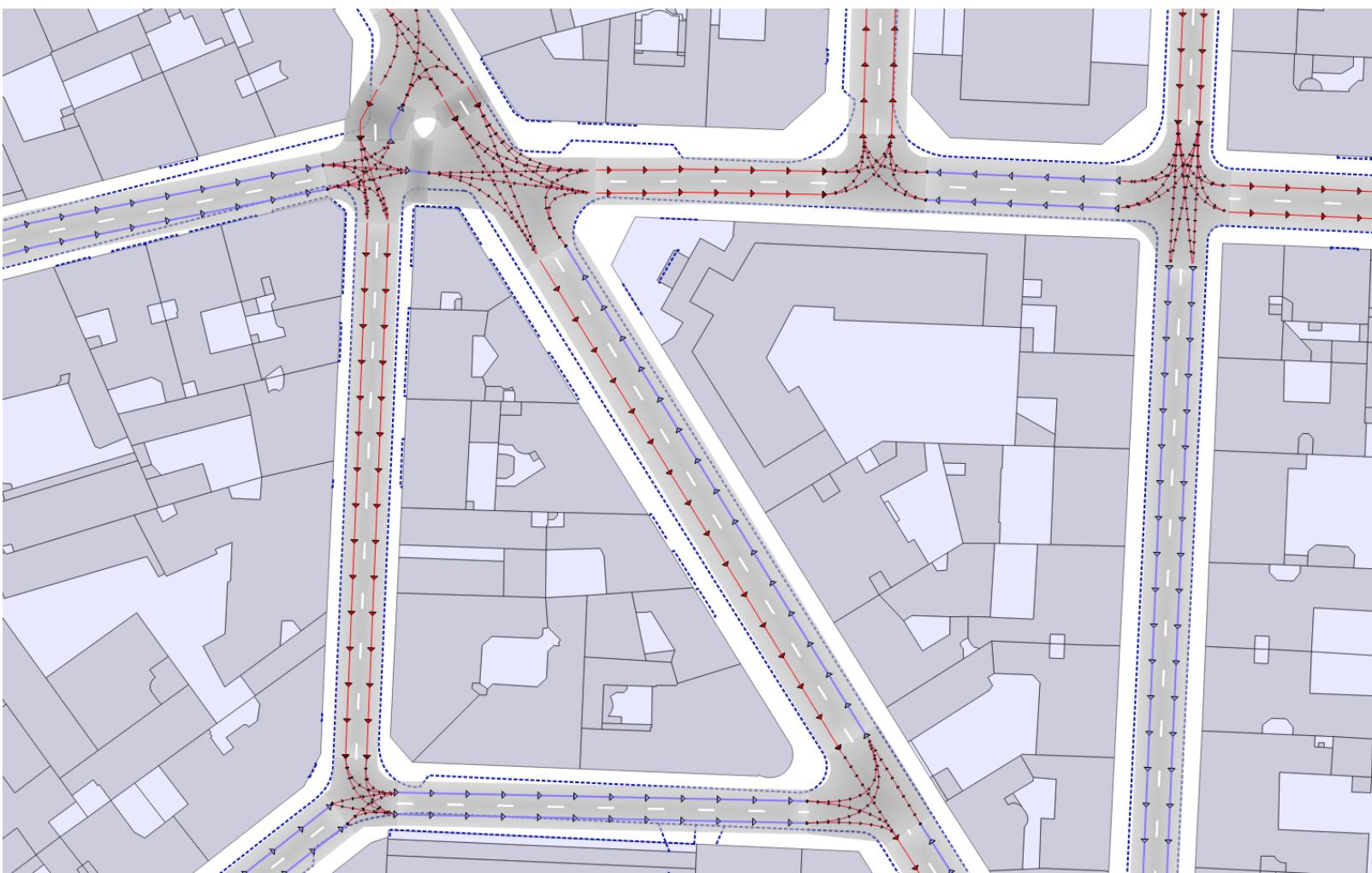
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- Traffic information is generated (but has not been optimised)



Inverse Procedural modelling: error sources

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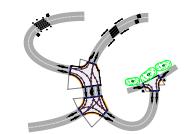
Streets

Interaction

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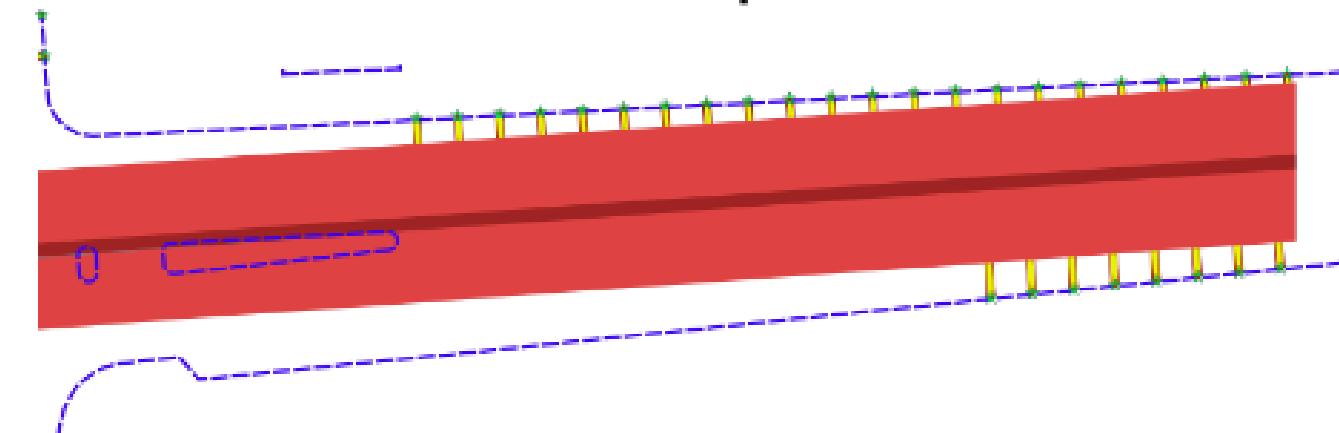
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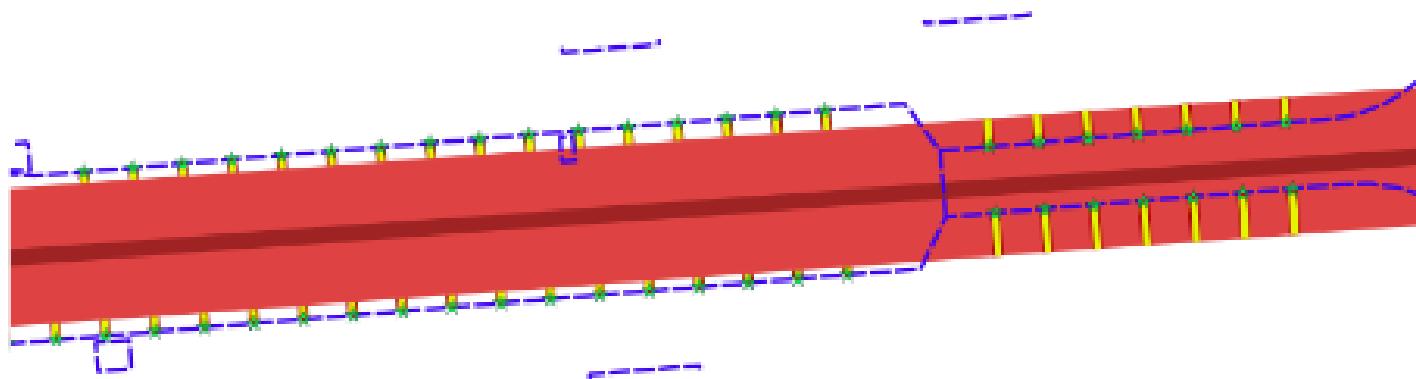


- Residual errors sources

Road model too simple

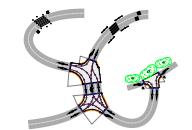


Over constrained (not enough split)



Inverse Procedural modelling: Limitations

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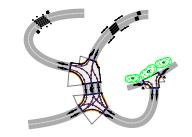


Contributions:

- Inverse procedural road modelling at city scale
- Fast and robust
- Generic observations formulation: can work with many objects

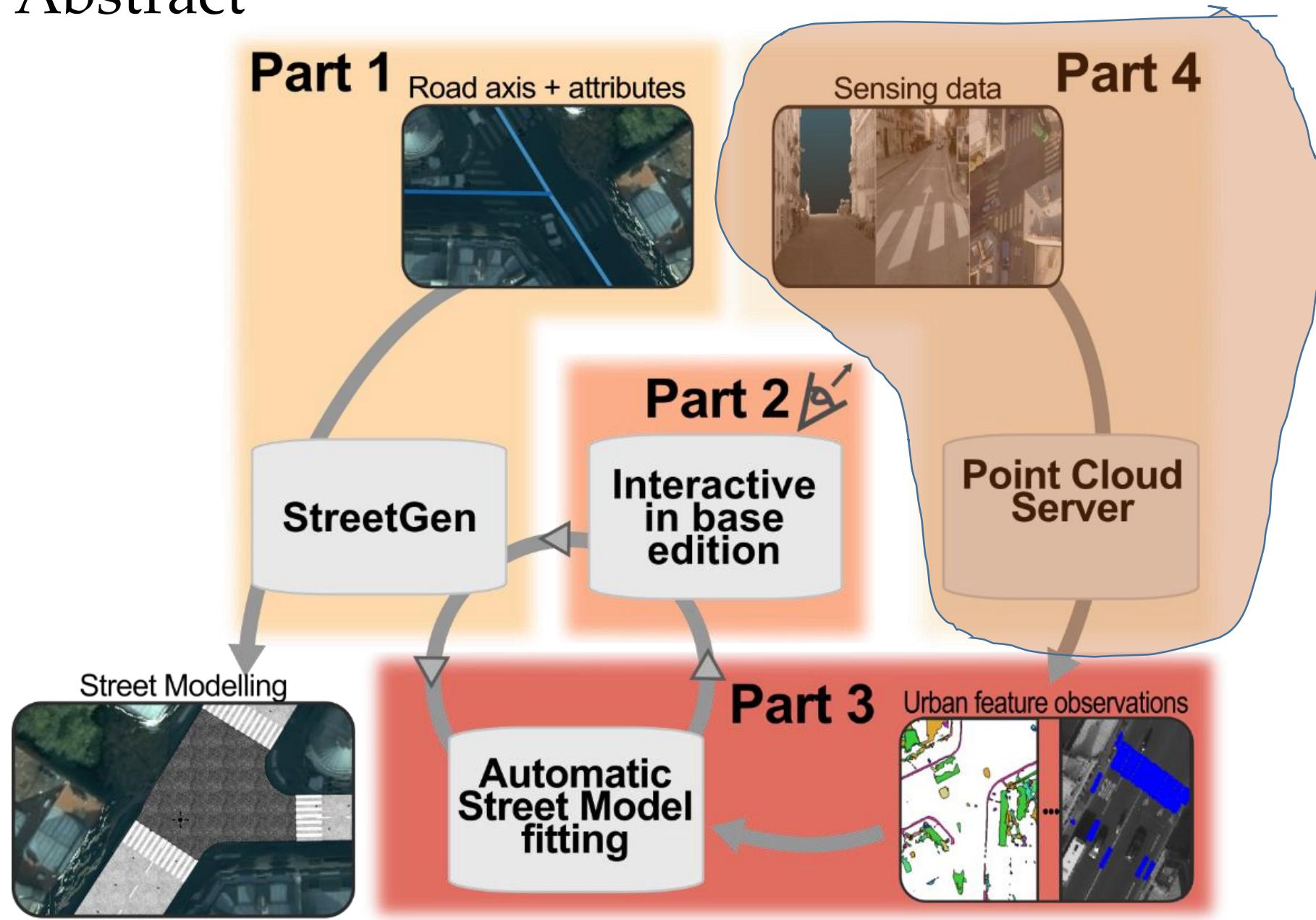
Inverse Procedural modelling: Limitations

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- Limitations
 - Only optimising a simplified road model (no radius)
 - Road model is too simple
 - Must choose between trusting initial model and trusting observations
 - Lacking regularisation forces for width (propagation)

Abstract



width= 8; lane= 3

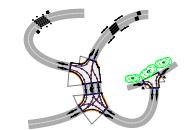
width= 6; lane= 2

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width= 4; lane= 1

Point Cloud Server: Data for observations

**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)

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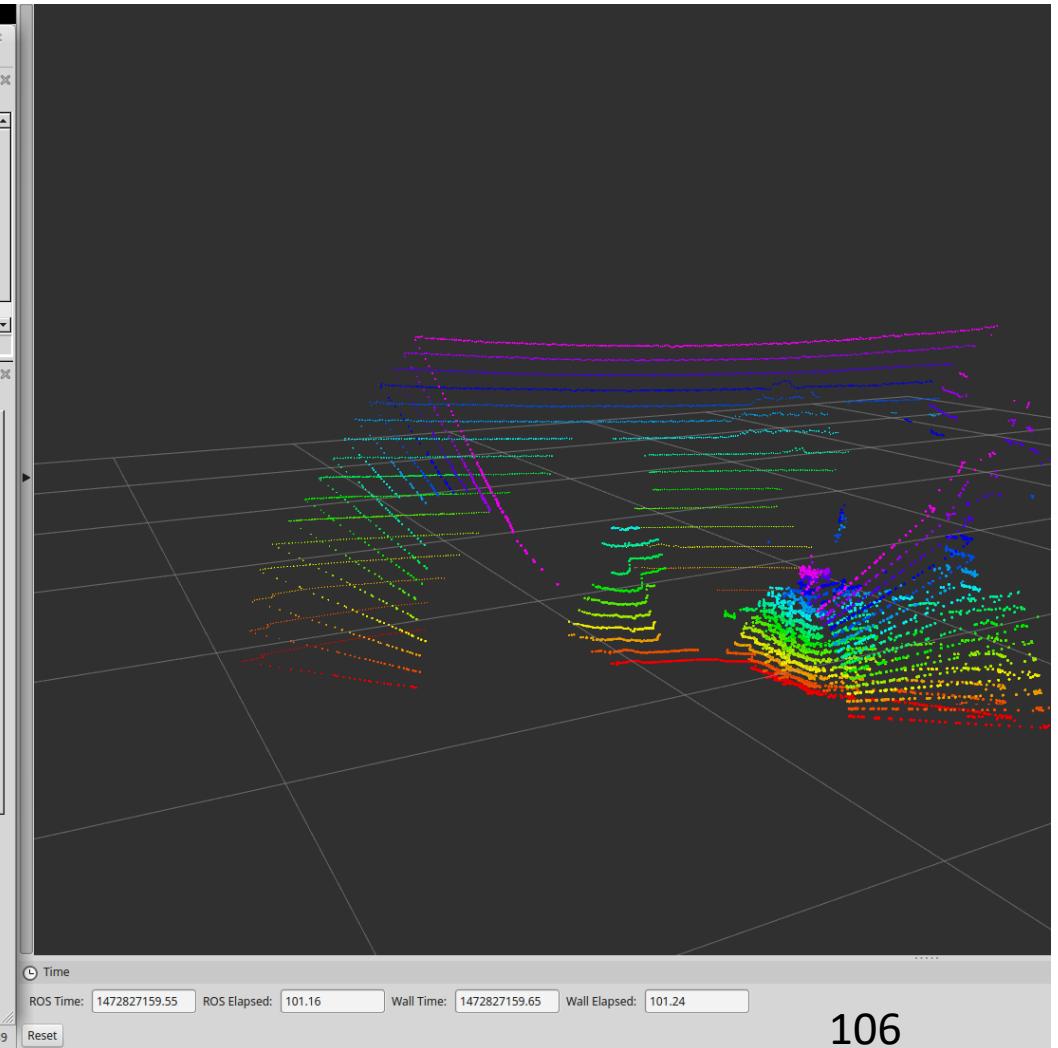
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width= 4; lane= 1

The screenshot shows a ROS (Robot Operating System) workspace with several windows open:

- Terminal:** Displays ROS commands and logs, including messages from a VLP webserver and sensor settings.
- Bag:** A viewer for ROS message bags.
- Li3DS GUI:** A graphical user interface for sensor data, showing fields like HV, A/D TD, Temp, and various voltage levels (5v, 2.5v, 3.3v, 5v Raw, VHv, 350).
- RViz:** A 3D visualization tool showing a point cloud from a Velodyne lidar sensor, colored by distance or reflectivity.



width= 8; lane= 3

width= 6; lane= 2

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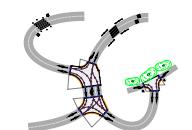
Conclusion

width= 4; lane= 1

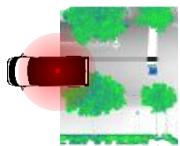
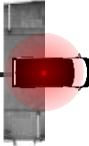
Data for observations: Point Cloud Server

Short introduction to Lidar

Point Cloud Server



Point Cloud Server



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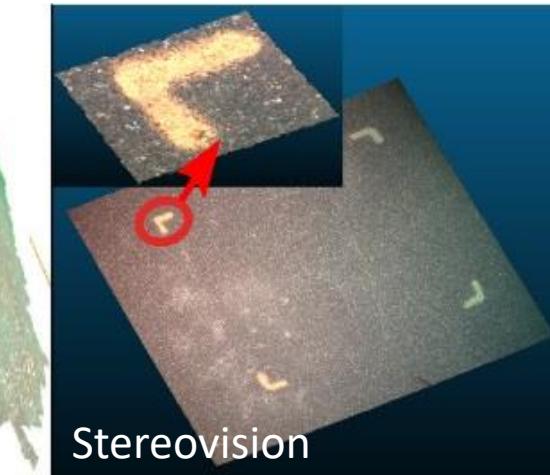
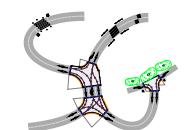
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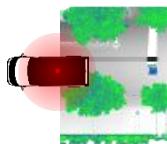
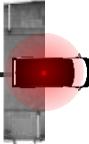
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Point Cloud Server: Problems



- Problem:
 - Massive data → need
 - Sharing
 - Filtering
 - Efficient I/O
 - Compression
 - Point cloud != only processing
 - We need a service!

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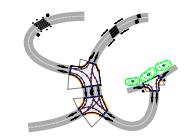
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Point Cloud Server: State of the art

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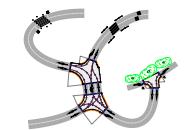
Streets

Interaction

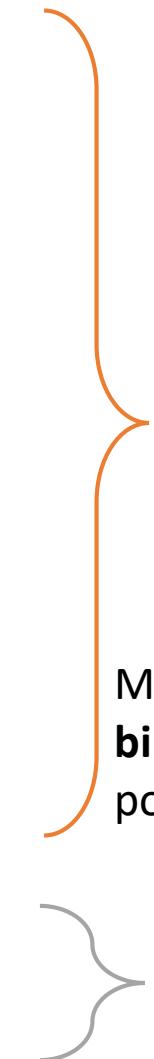
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- File-based
 - Simple, no concurrency
 - Can't do much with points
- DBMS (point storing)
 - Powerful
 - Can't scale
- NoSQL
 - Scale well
 - Specific and tailored
- Cloud
 - Ultimate scaling
 - Theoretical problem with indexing
- DBMS (group of points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



Otepka et al., 2013

Rieg et al., 2014

van Oosterom et al., 2015

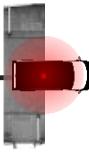
Managing
billions of nD-
points : difficult !

≠

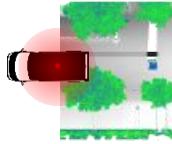
Managing **million**s
of groups of points: e

Grey

Todo : simplify, images



Point Cloud Server: Method



- Idea:

PCS = a ... server !

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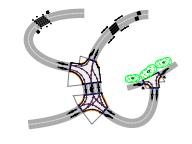
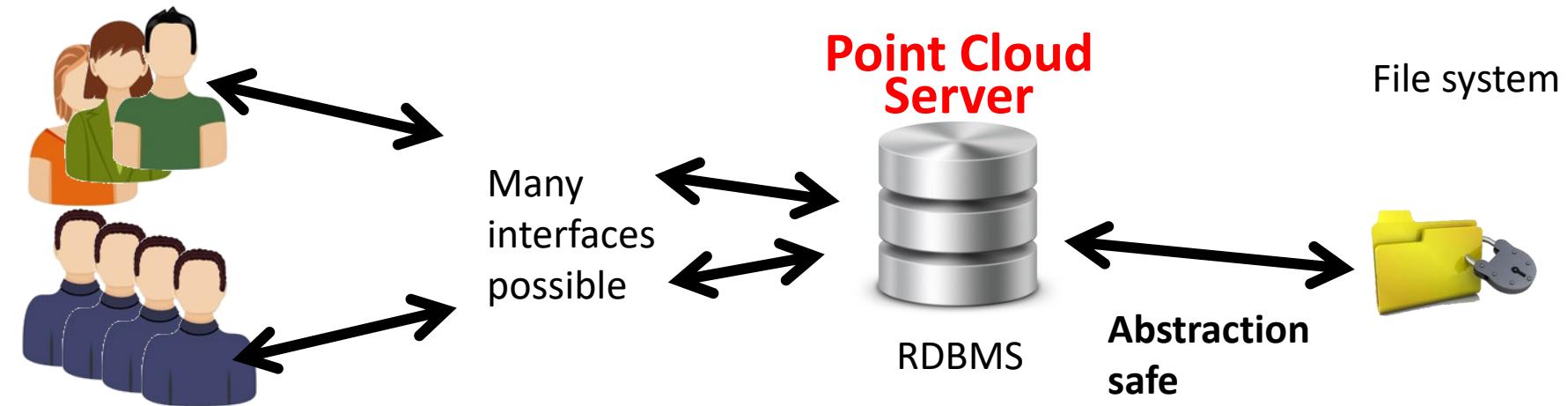
Streets

Interaction

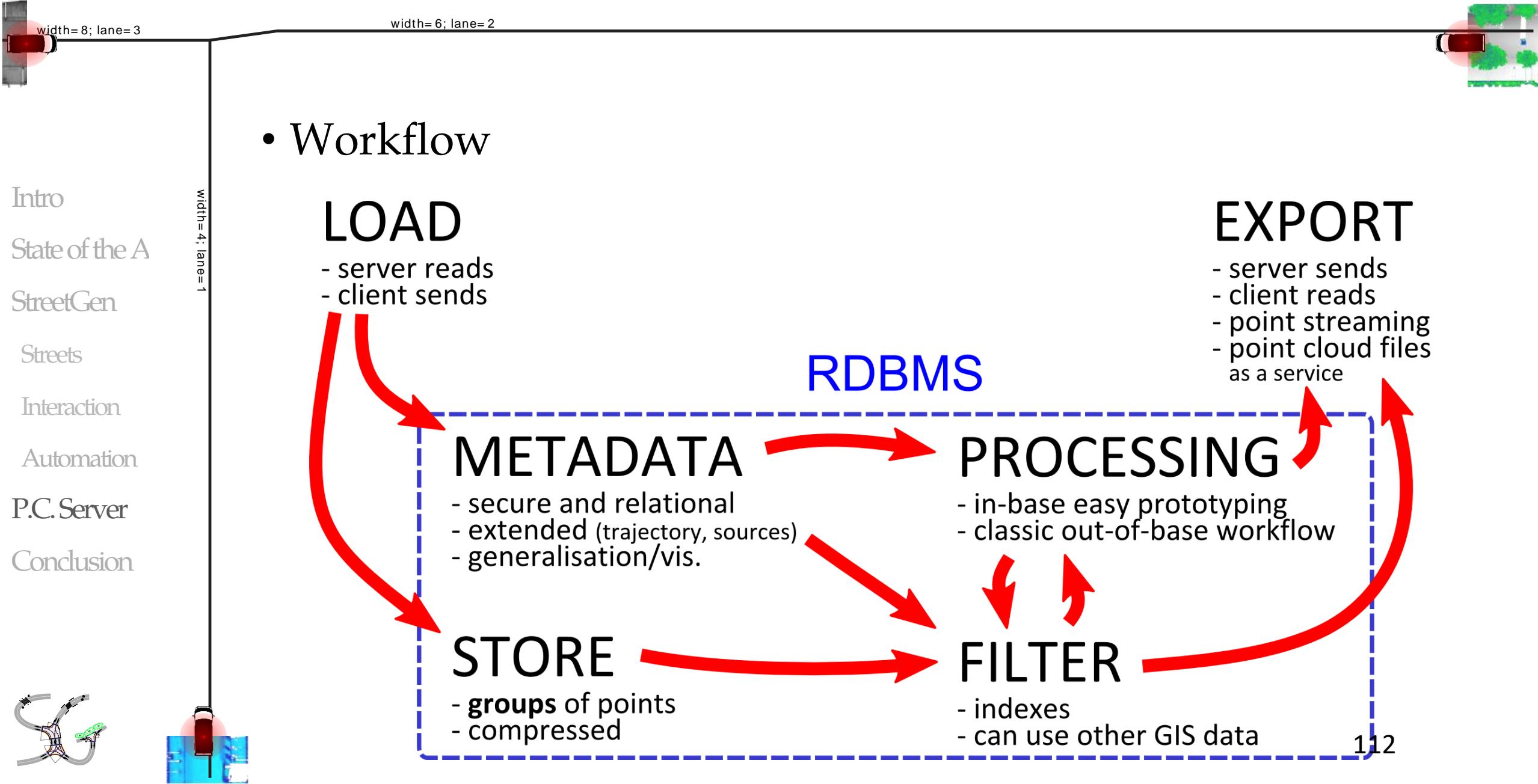
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Point Cloud Server: Method



Point Cloud Server: Loading/Exporting



Point Cloud Server: Loading/Exporting



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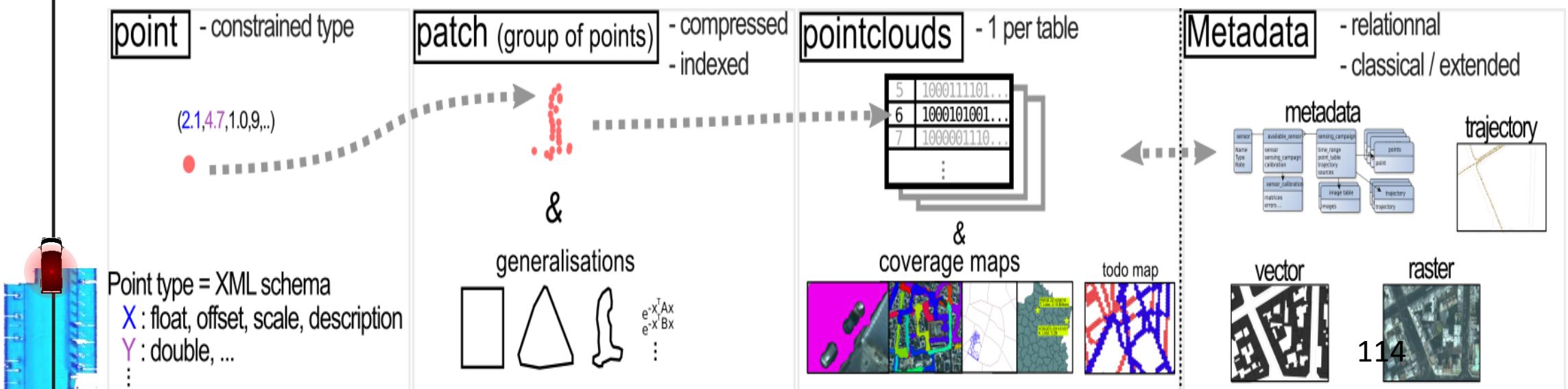
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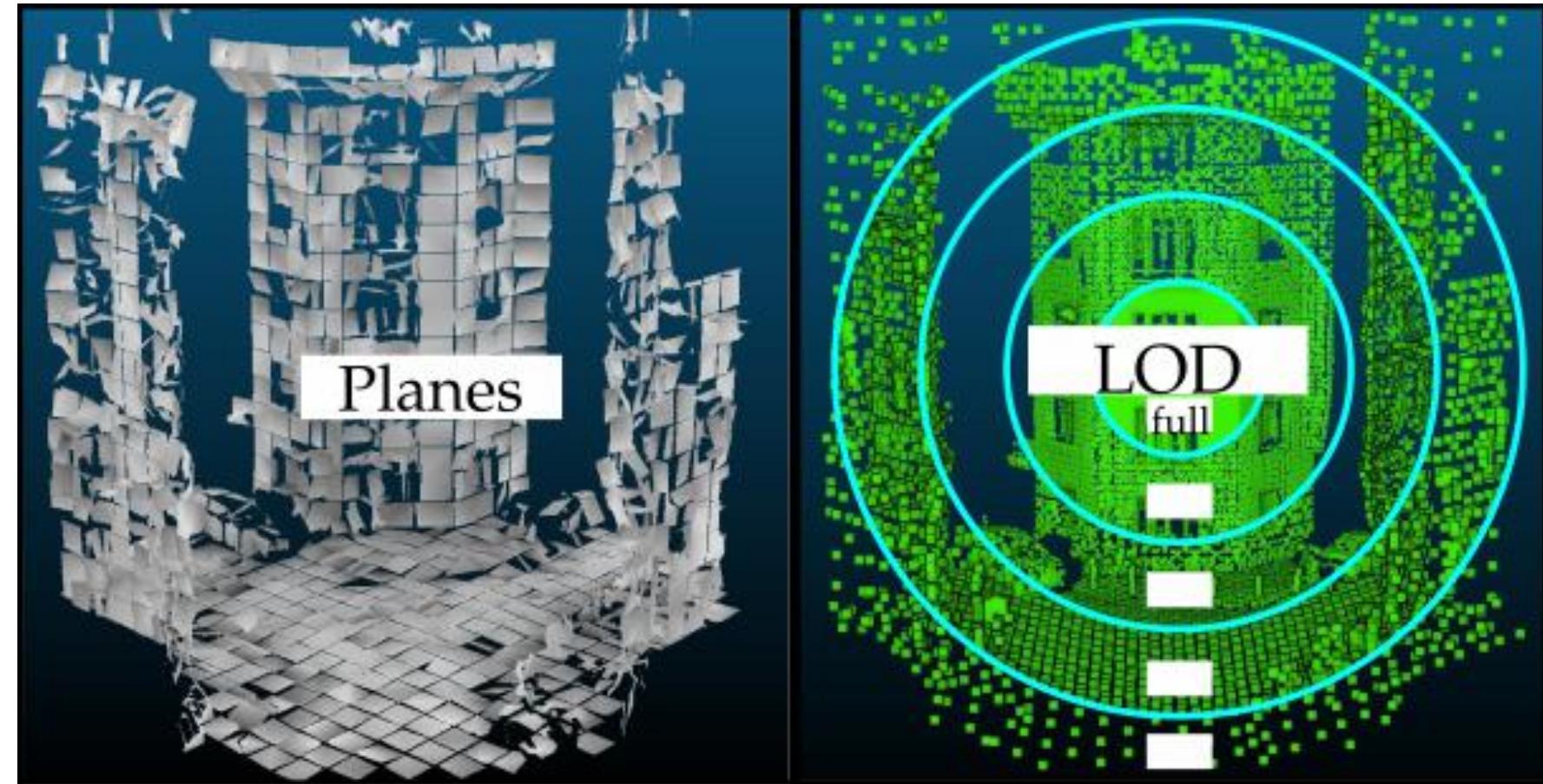
- Paris loading speed: 75k pts/s writing : 200k pts/s
 - Not far from actual sensing speed
 - Could be faster ([Vanoosterom2015](#))
- We load point clouds, but how are they stored?



Point Cloud Server: generalisation



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



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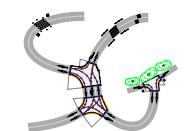
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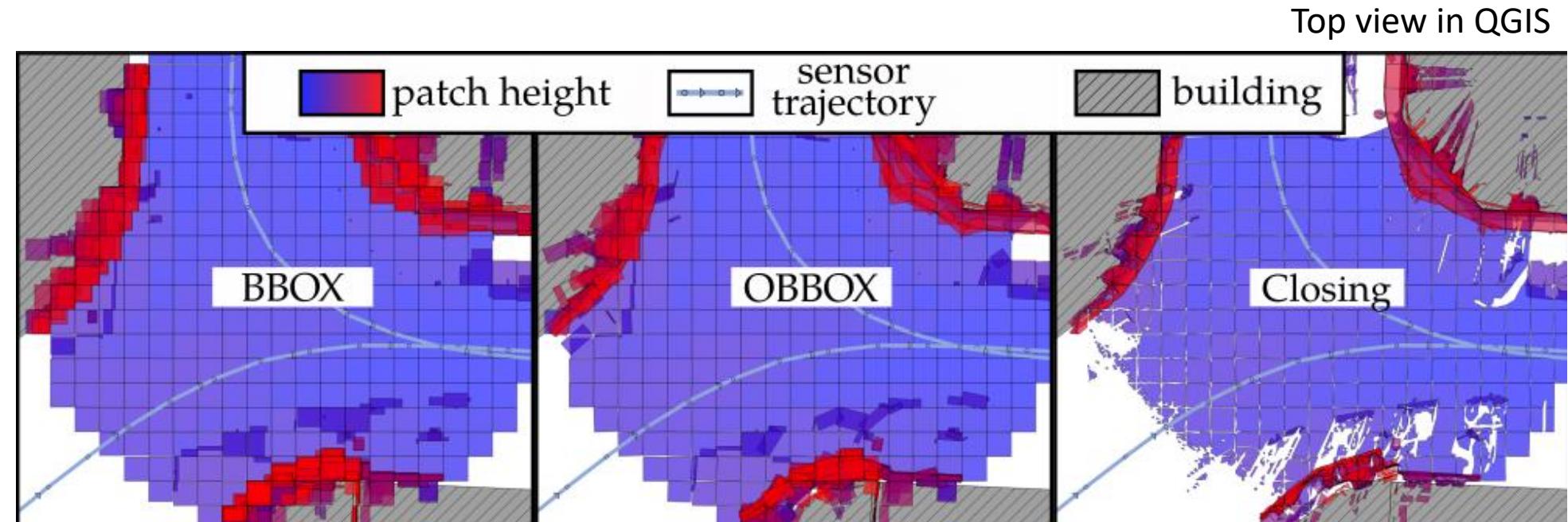
Point Cloud Server: generalisation



- 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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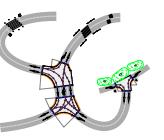
Streets

Interaction

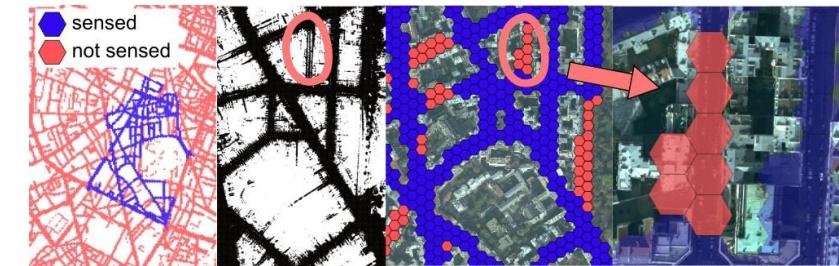
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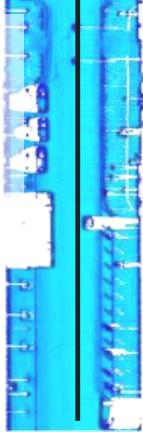
width=4; lane=1



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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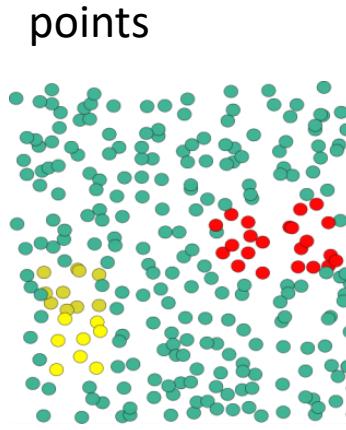
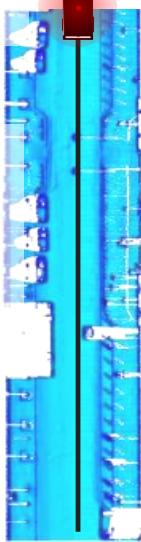
Streets

Interaction

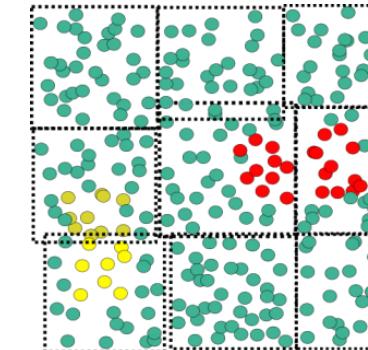
Automation

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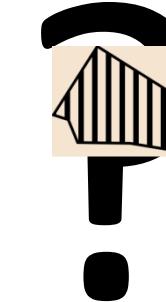
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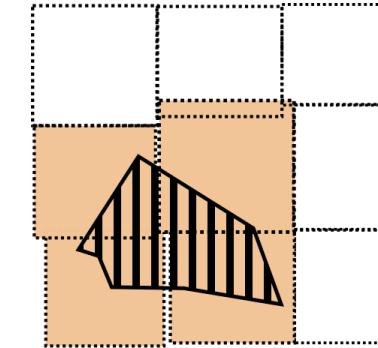
Points in patch



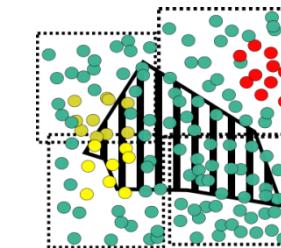
Which points
are inside the
polygon?



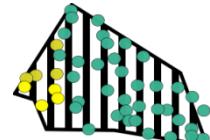
Which **patchs**
are inside the
polygon?



Get points in
these patches



Which
points are
inside the
polygon?



Point Cloud Server: processing



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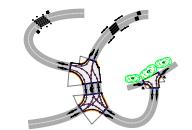
Streets

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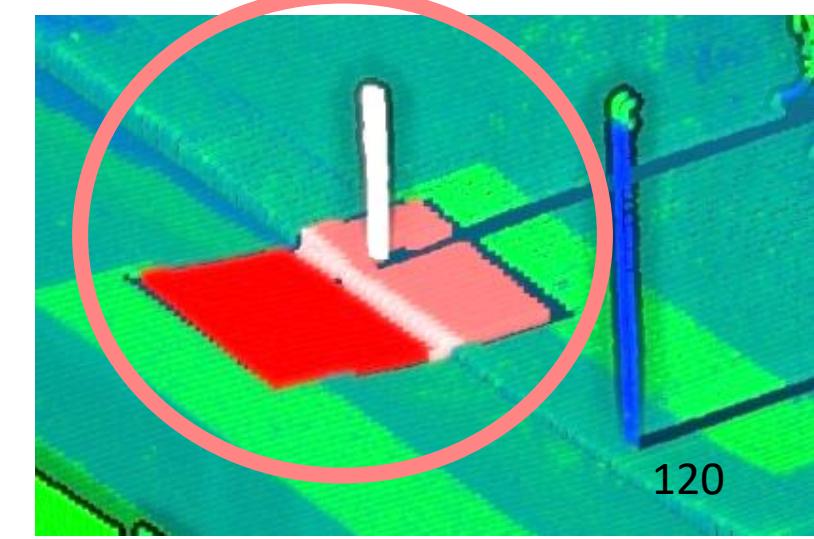
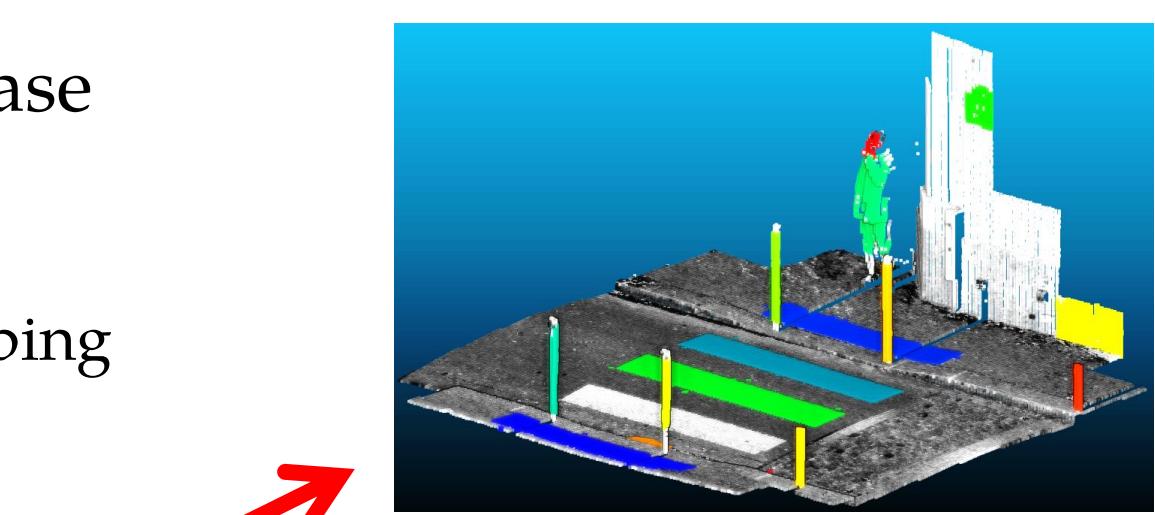
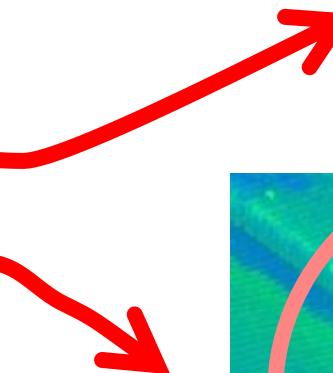
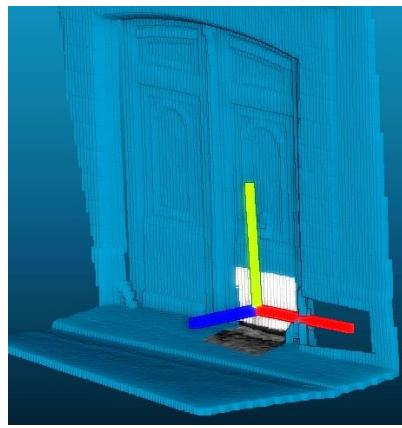


- Postgresql: easy to add in-base processing

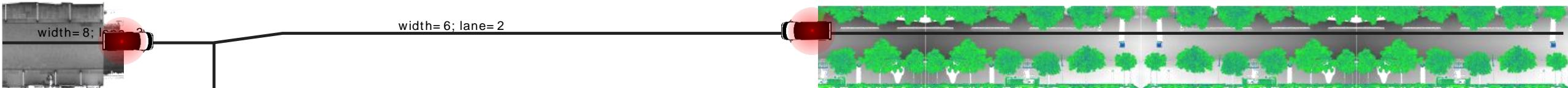
- C/Cpp → for performance
- R/Python → for fast prototyping

- Example :

- Verticality descriptor
- Unsupervised clustering
- Plane & cylinder detection



Point Cloud Server: processing



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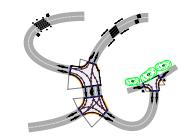
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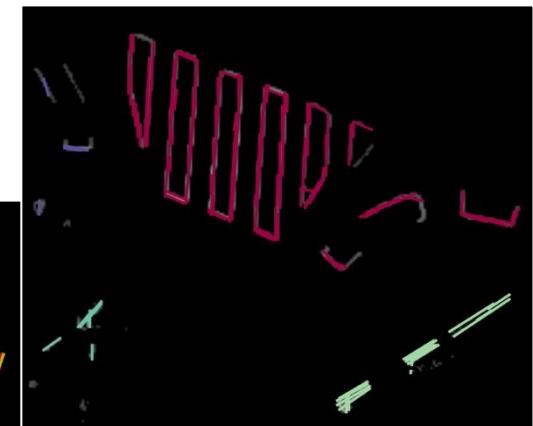
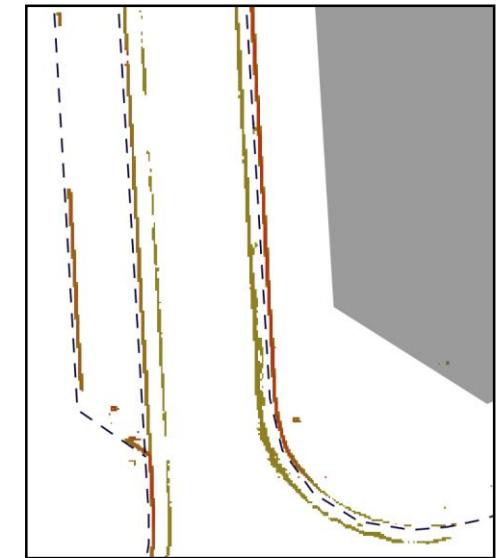
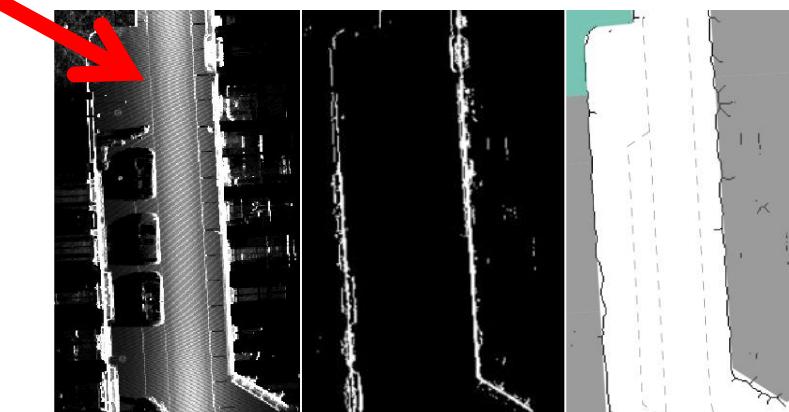
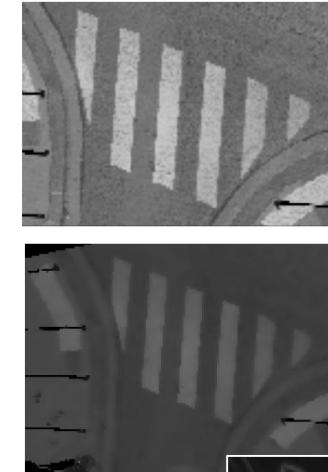
Automation

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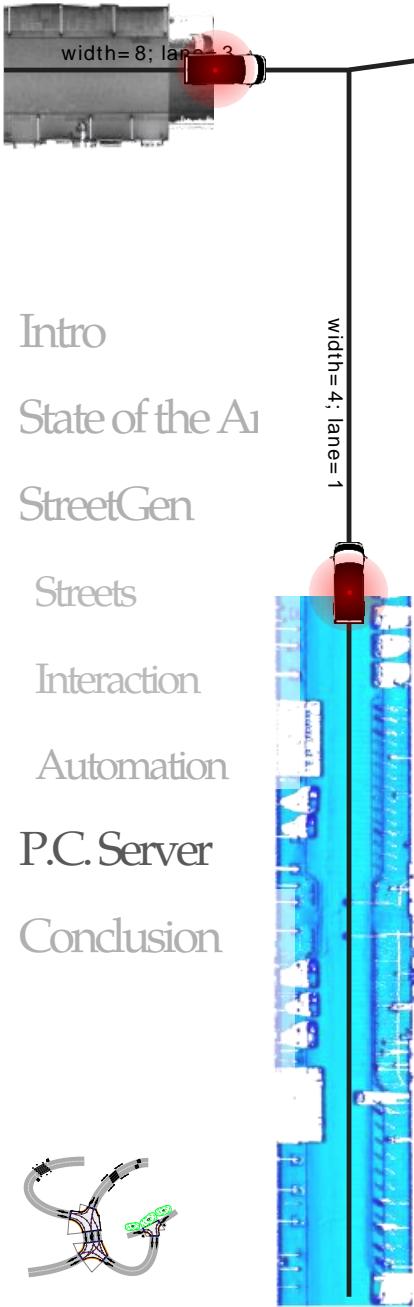
Conclusion



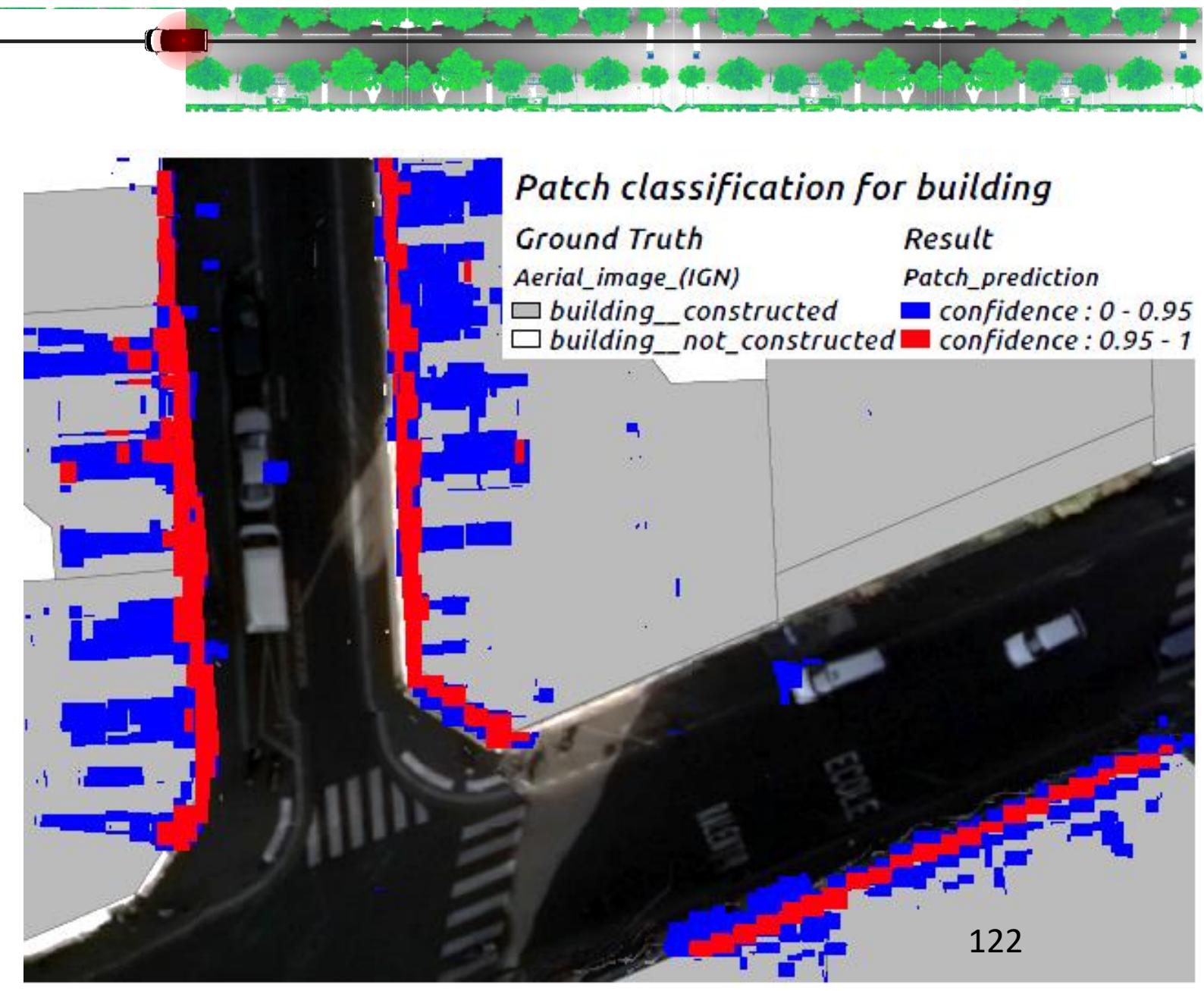
- Converting patch to raster
 - Cornerstone detection
 - Marking detection
 - Façade detection



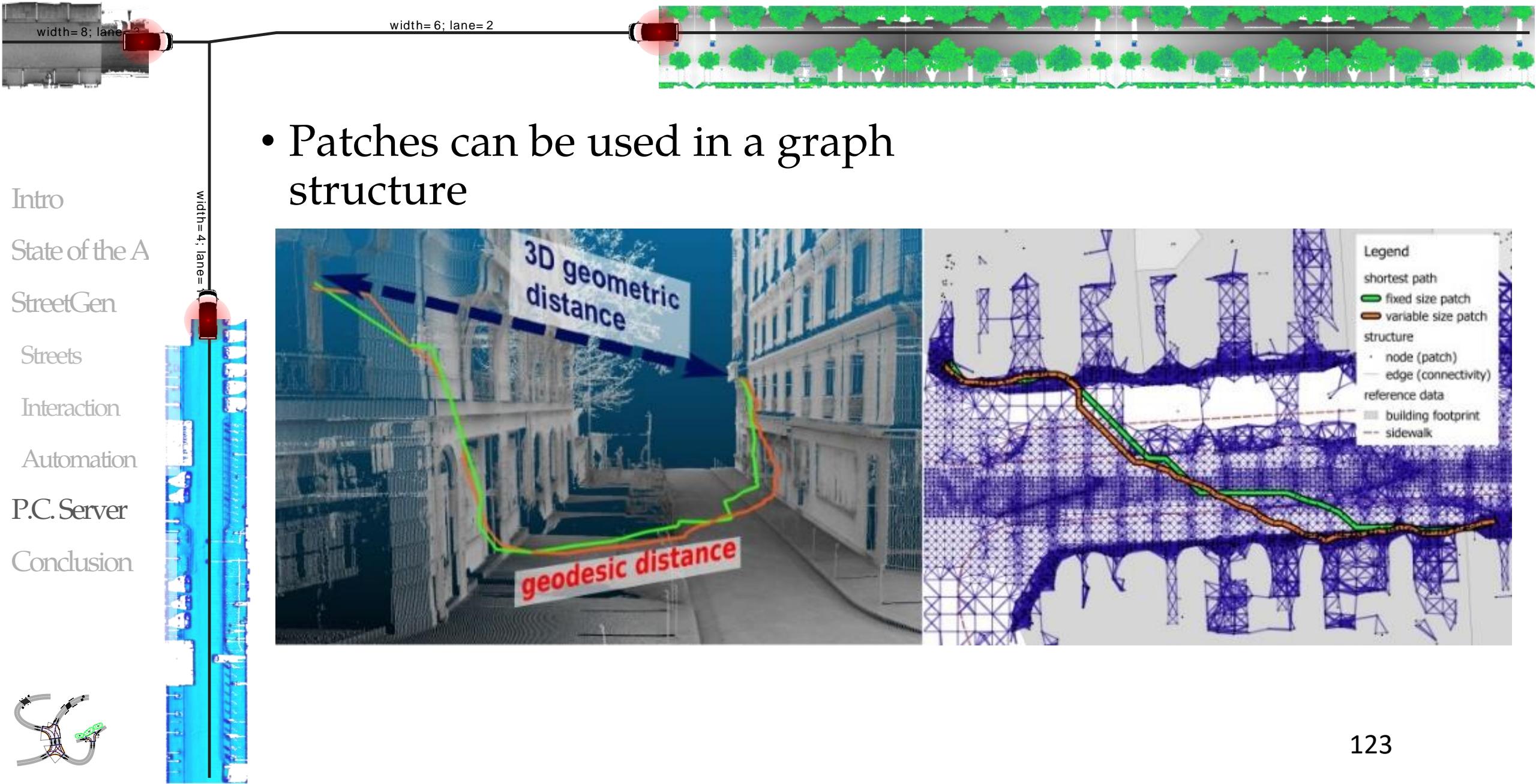
Point Cloud Server: processing



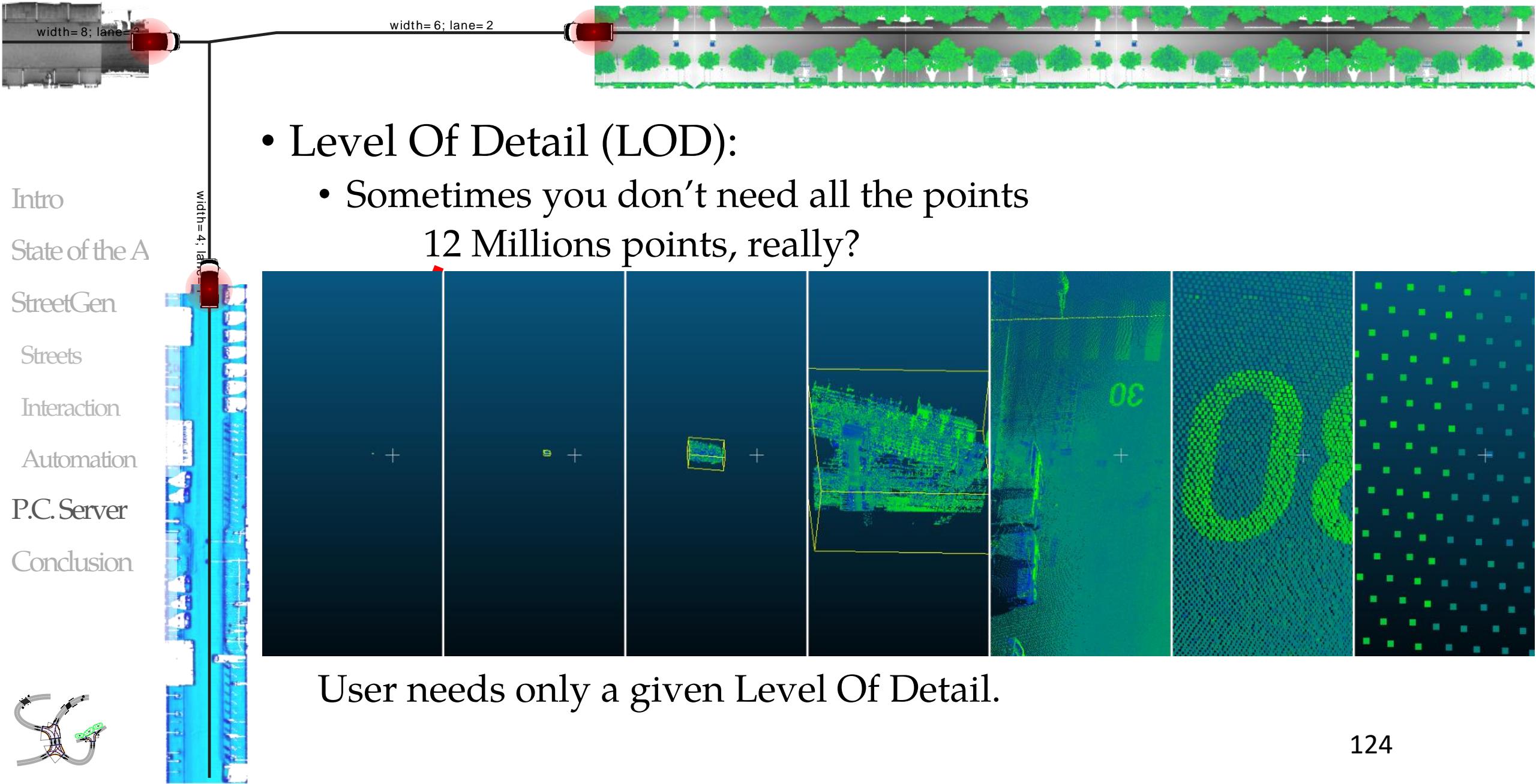
- classification



Point Cloud Server: processing



Point Cloud Server: Level Of Detail



The diagram illustrates the concept of Level Of Detail (LOD) in a point cloud server. At the top, a street scene is shown with two segments highlighted: one segment has a width of 8 lanes and another has a width of 6 lanes. Below this, a vertical bar represents the LOD levels, with labels indicating width and lane counts. The bar starts at a width of 8 lanes, then drops to 6 lanes, then to 4 lanes, and finally to 2 lanes. A red light is positioned above each of these segments. To the right of the bar, a series of seven images show a cross-section of a road surface, with each image becoming progressively more detailed (higher LOD). The first three images are very dark, while the last four show increasing numbers of green points representing the point cloud. A yellow box highlights a specific area in the fourth image, and a yellow line indicates a zoomed-in view of the fifth image. The sixth and seventh images show a highly detailed view of a circular feature, likely a manhole or drain, with many green points.

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

User needs only a given Level Of Detail.

width=8; lane=2

width=6; lane=2

width=4; lane=2

width=2; lane=1

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Point Cloud Server: Level Of Detail



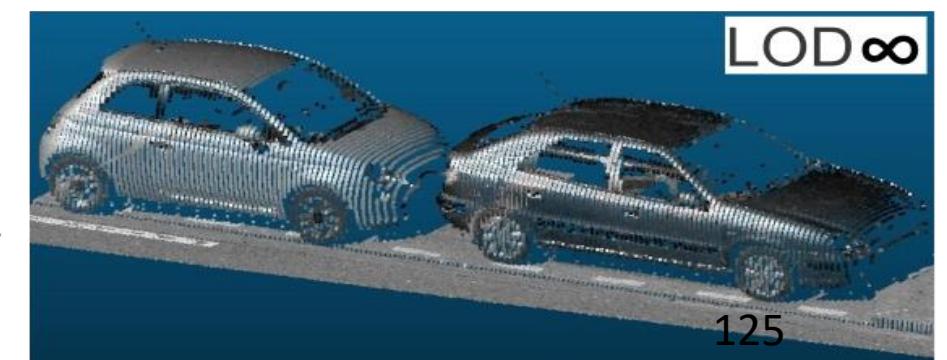
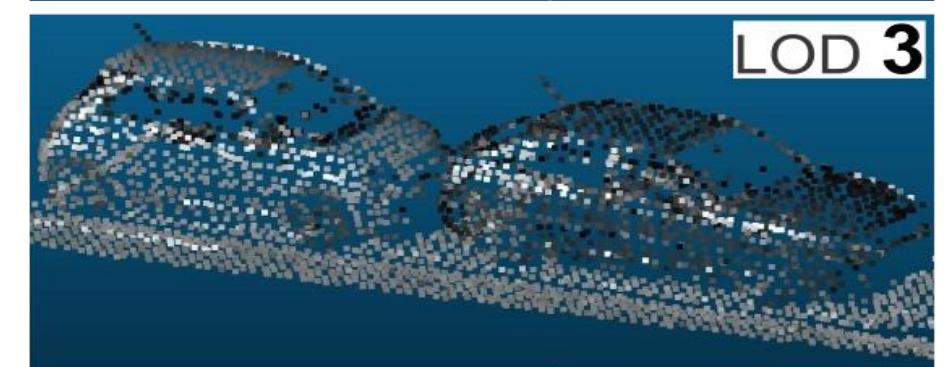
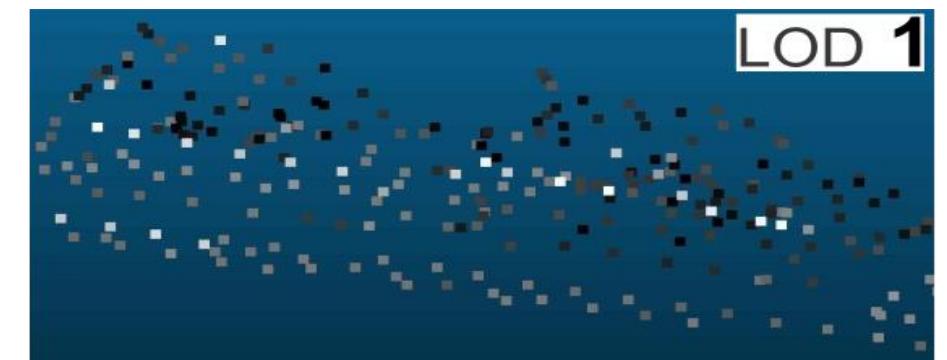
- Idea : implicit LOD
 - order the point by importance
 - Reading the points gradually increases the level of detail



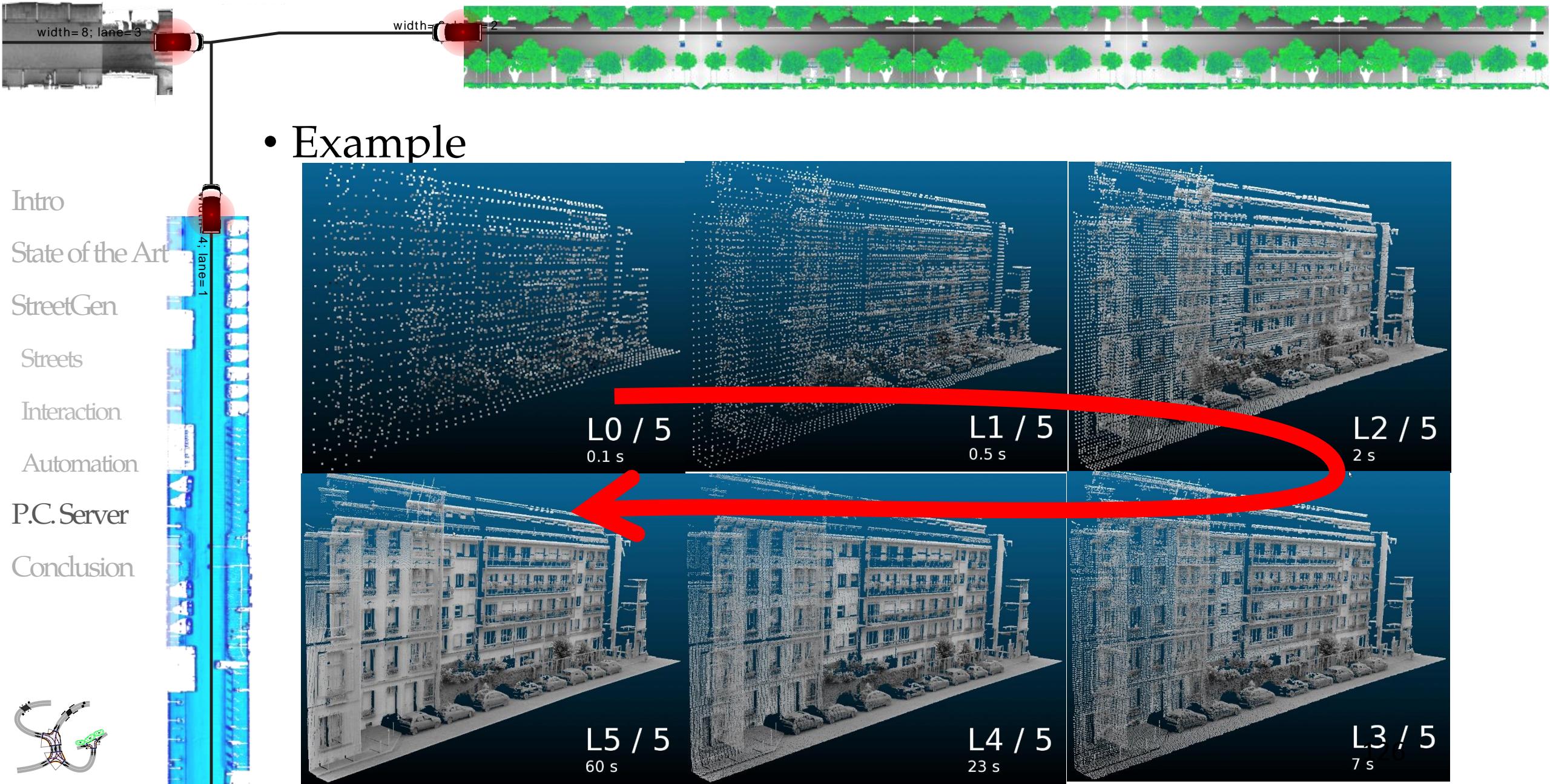
points
order :

1
2
3
4
⋮

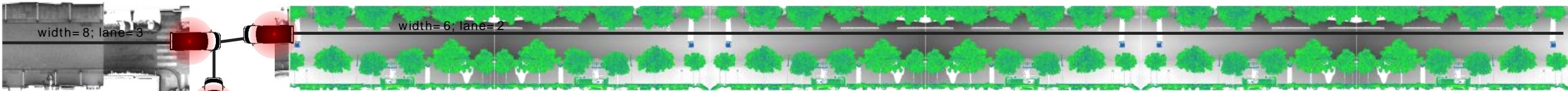
↓
N



Point Cloud Server: Level Of Detail



Point Cloud Server: Level Of Detail



- LOD enables point streaming

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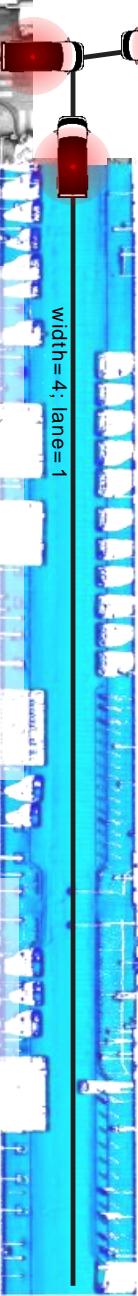
Streets

Interaction

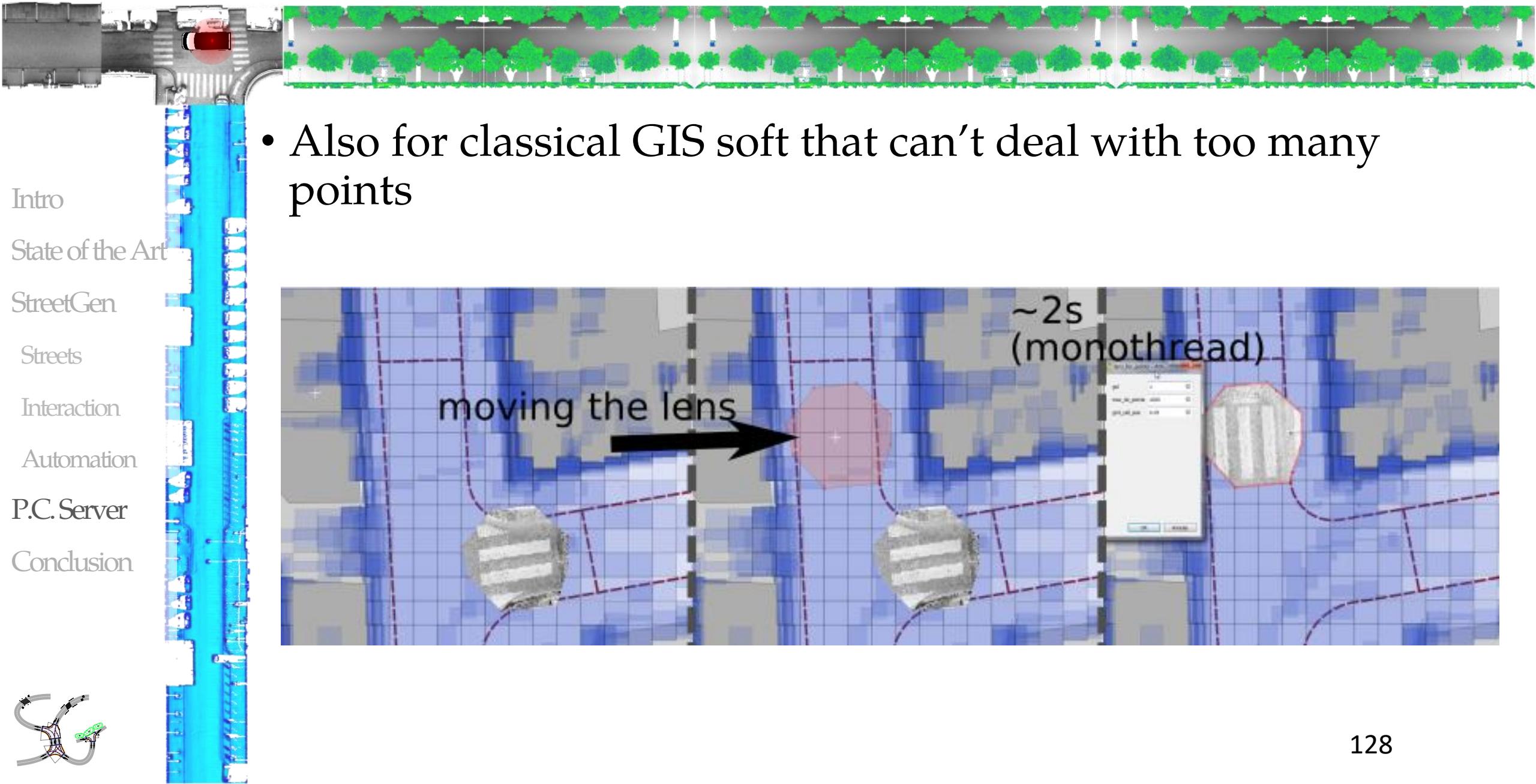
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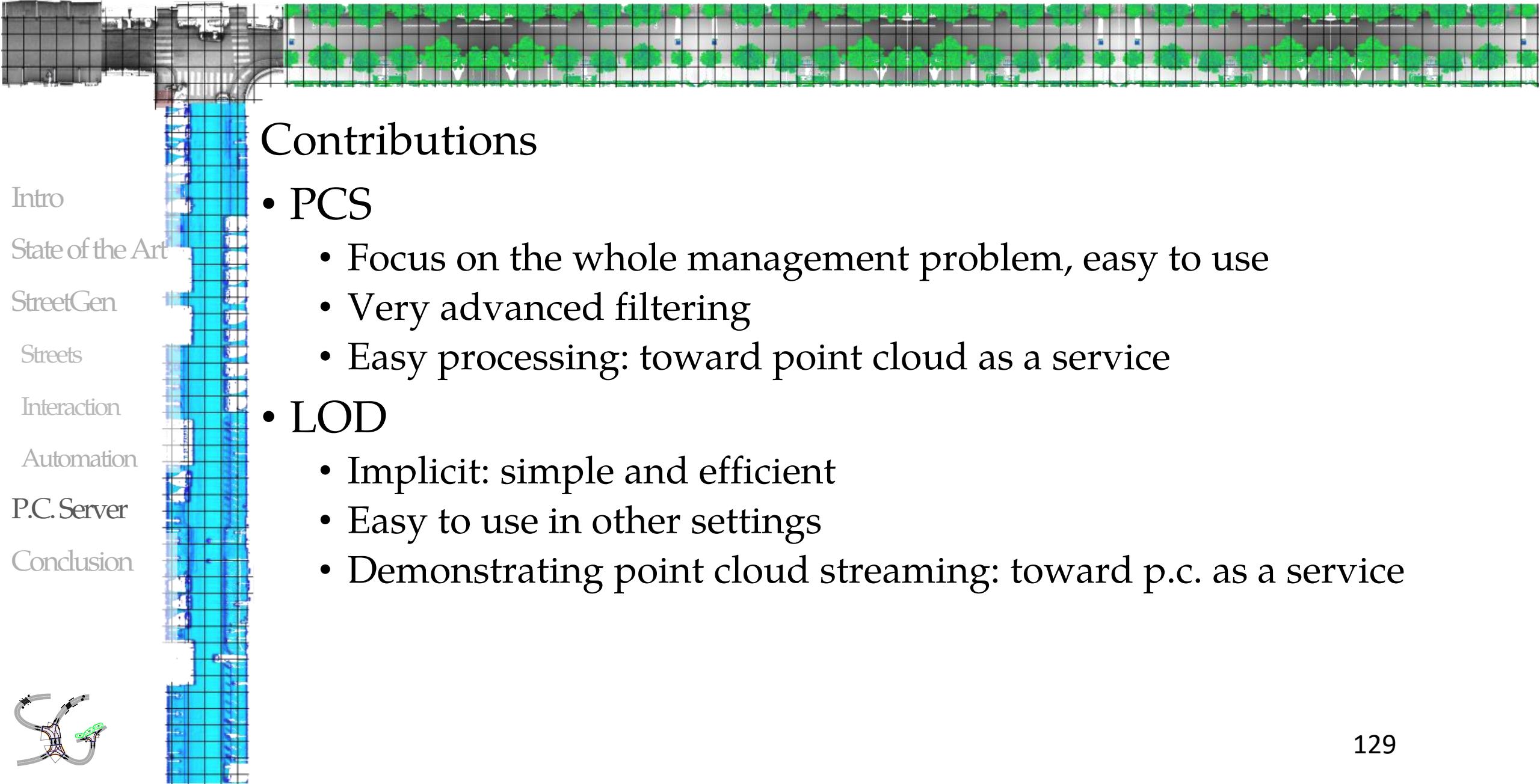
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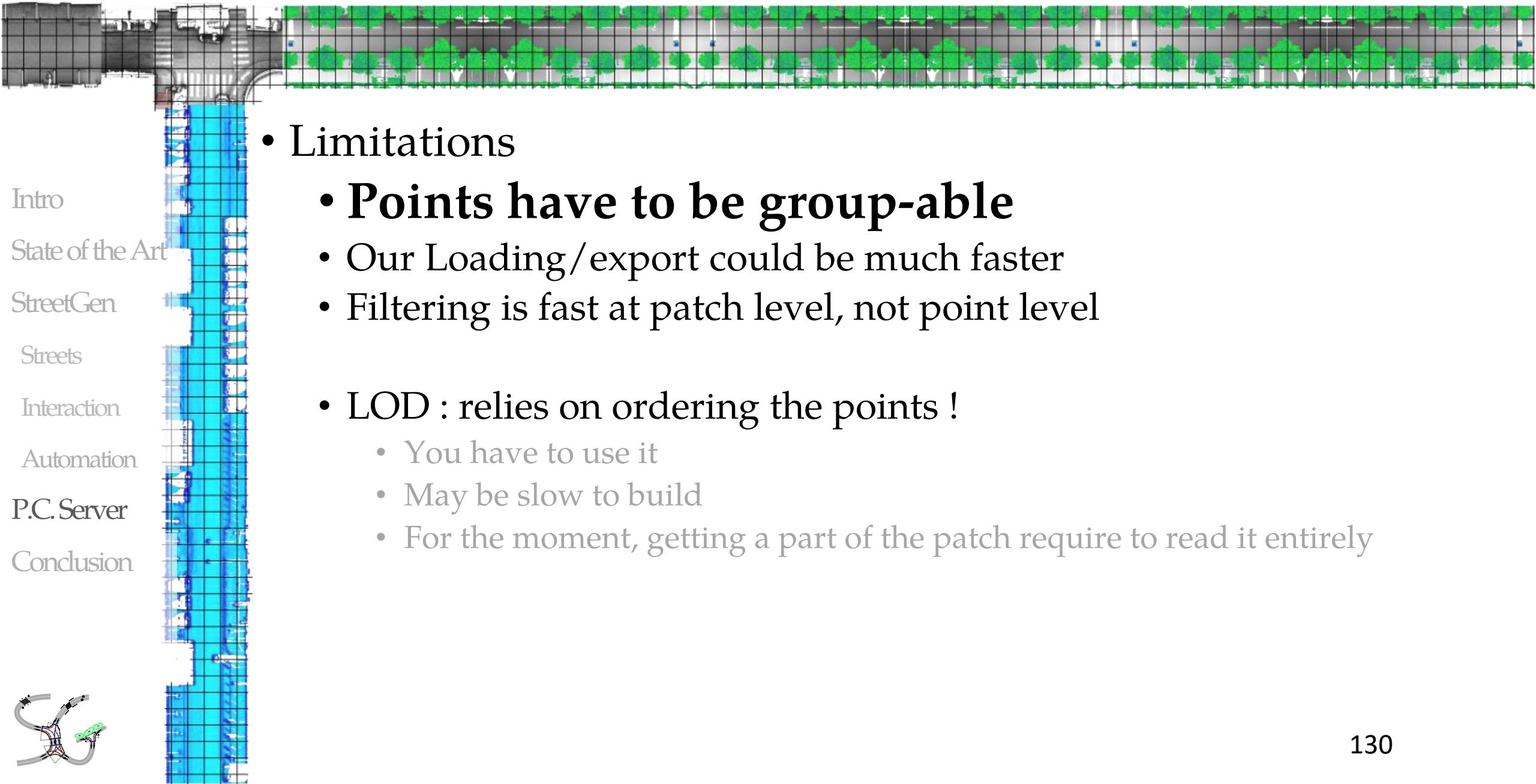
Point Cloud Server: Level Of Detail



Contributions

- PCS
 - Focus on the whole management problem, easy to use
 - Very advanced filtering
 - Easy processing: toward point cloud as a service
- LOD
 - Implicit: simple and efficient
 - Easy to use in other settings
 - Demonstrating point cloud streaming: toward p.c. as a service

Point Cloud Server: Level Of Detail



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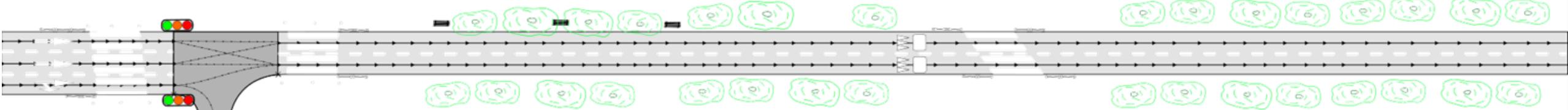
- Limitations

- **Points have to be group-able**

- Our Loading/export could be much faster
 - Filtering is fast at patch level, not point level

- LOD : relies 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



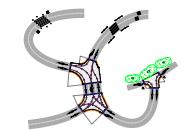
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Perspectives



Conclusion: Summary

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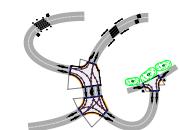
Streets

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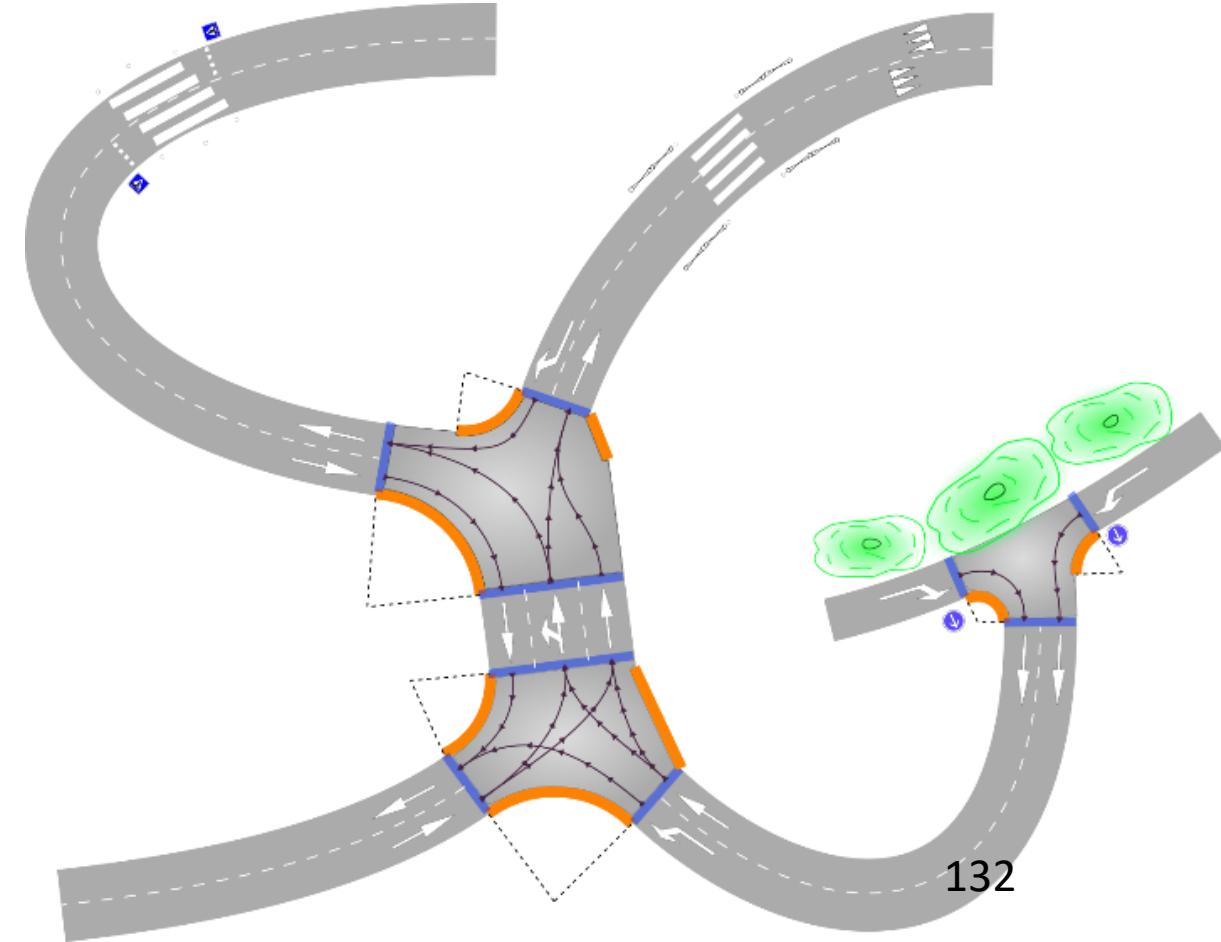
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- From low information: generate best guess street model at Paris scale and edit it (multi-user, using many GIS software): StreetGen



Conclusion: Summary

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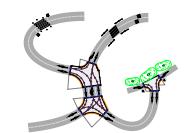
Streets

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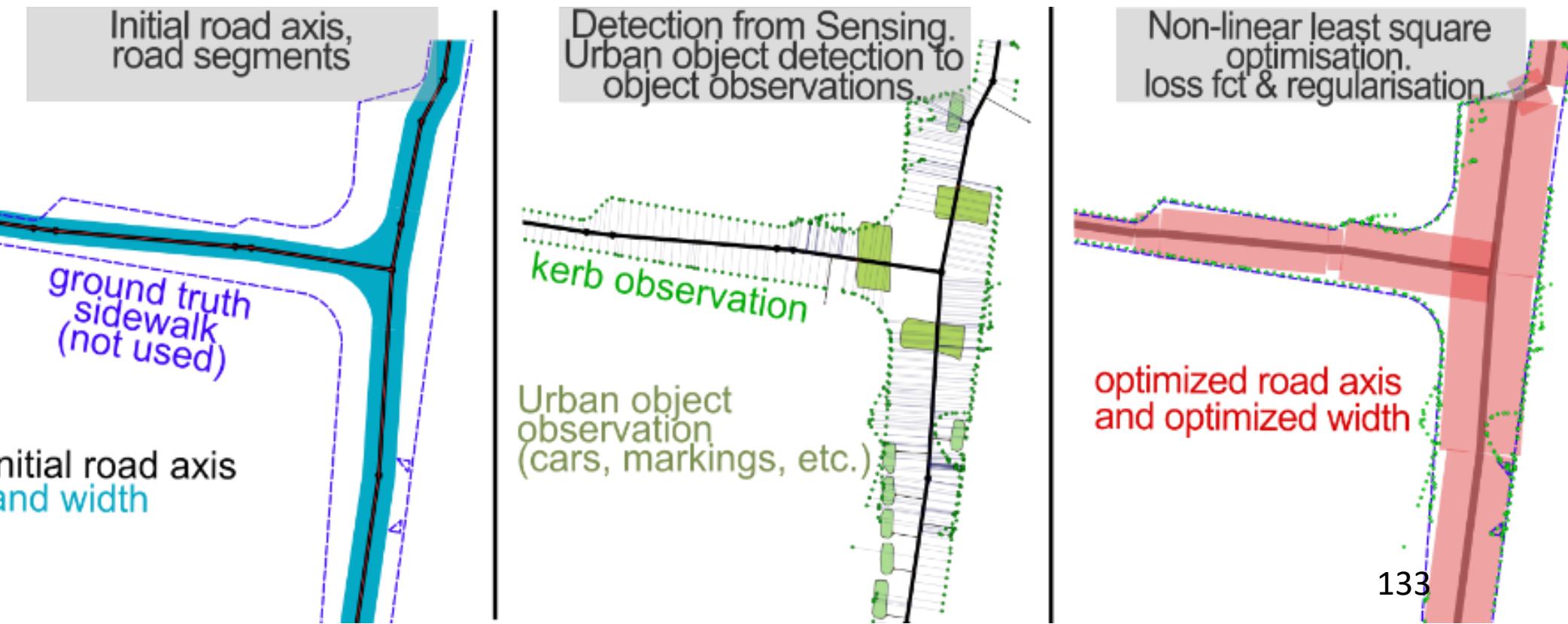
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- Perform inverse procedural modelling by fitting a road model to various observations



Conclusion: Summary

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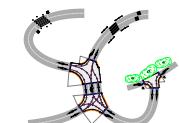
Streets

Interaction

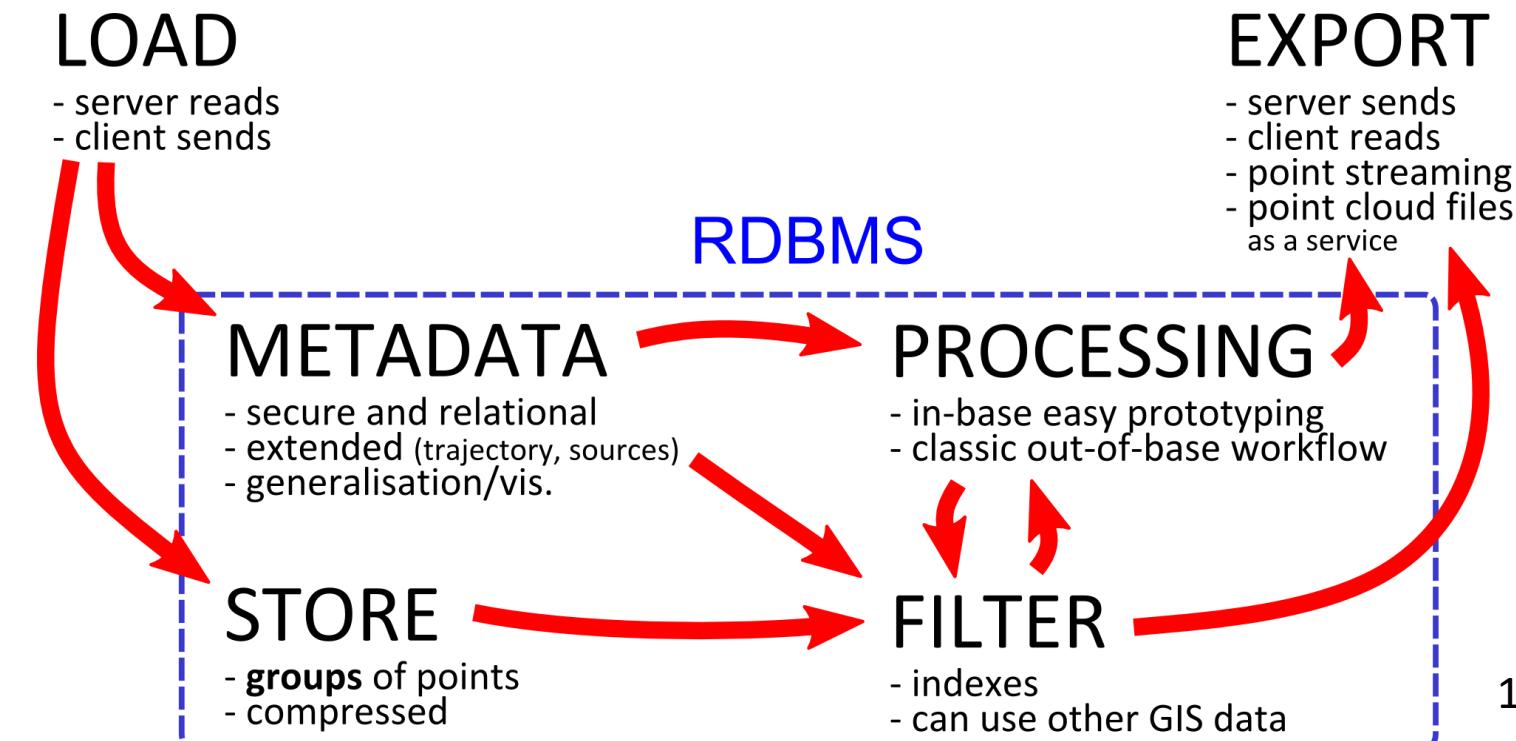
Automation

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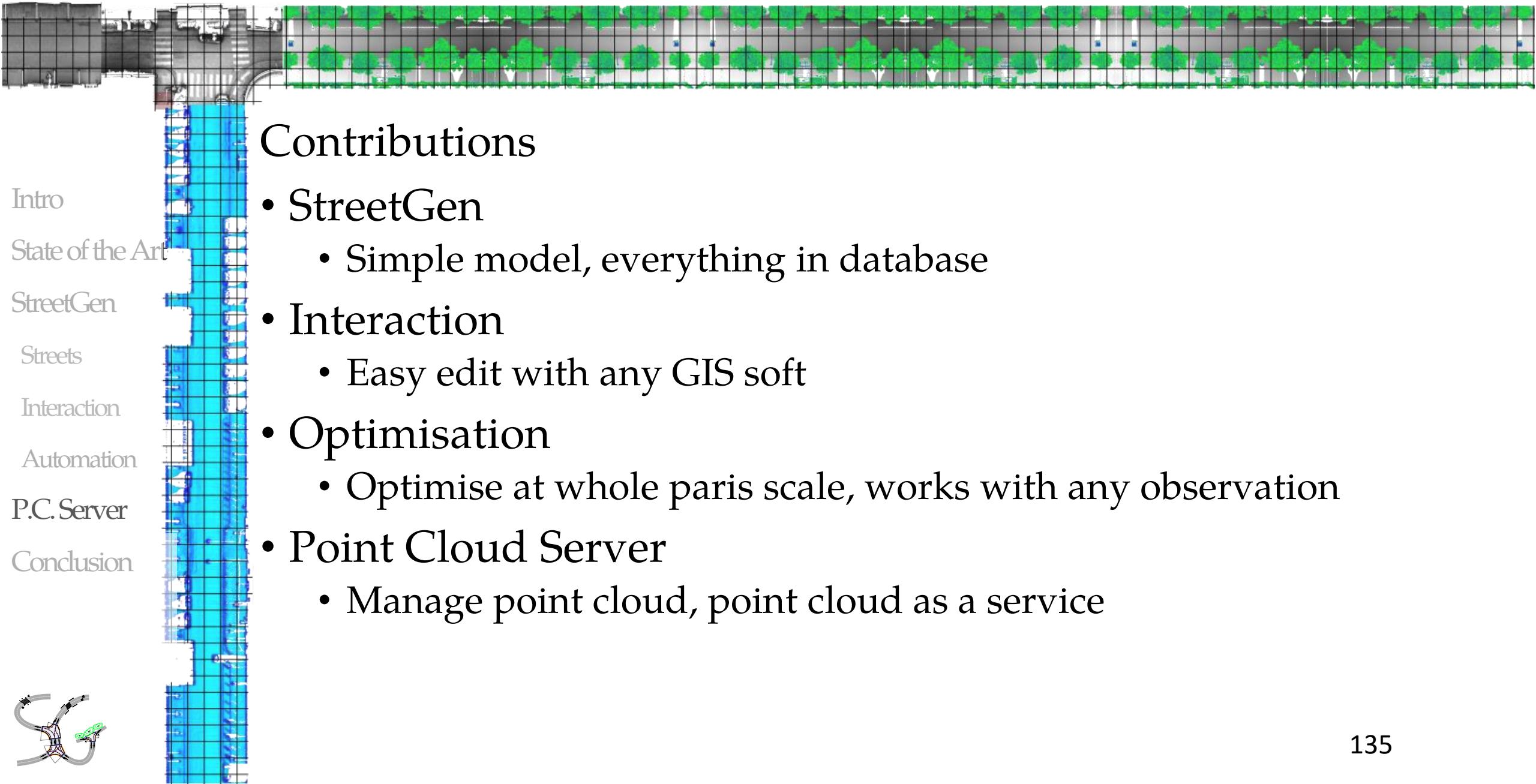
Conclusion



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



Point Cloud Server: Level Of Detail



Contributions

- StreetGen
 - Simple model, everything in database
- Interaction
 - Easy edit with any GIS soft
- Optimisation
 - Optimise at whole paris scale, works with any observation
- Point Cloud Server
 - Manage point cloud, point cloud as a service

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StreetGen

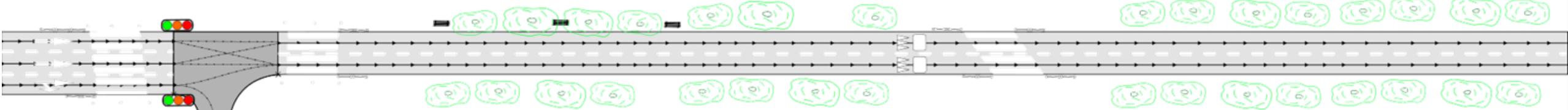
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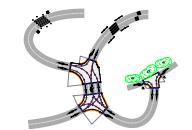
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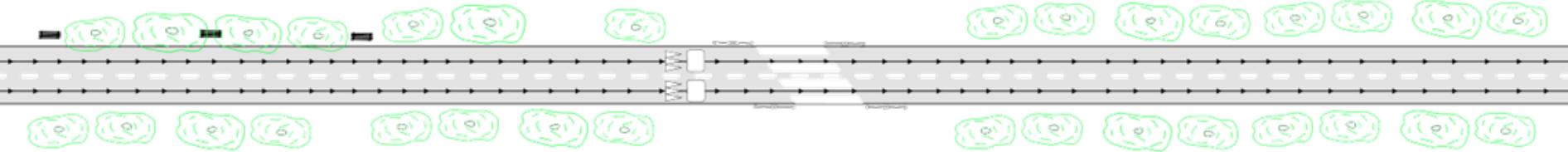
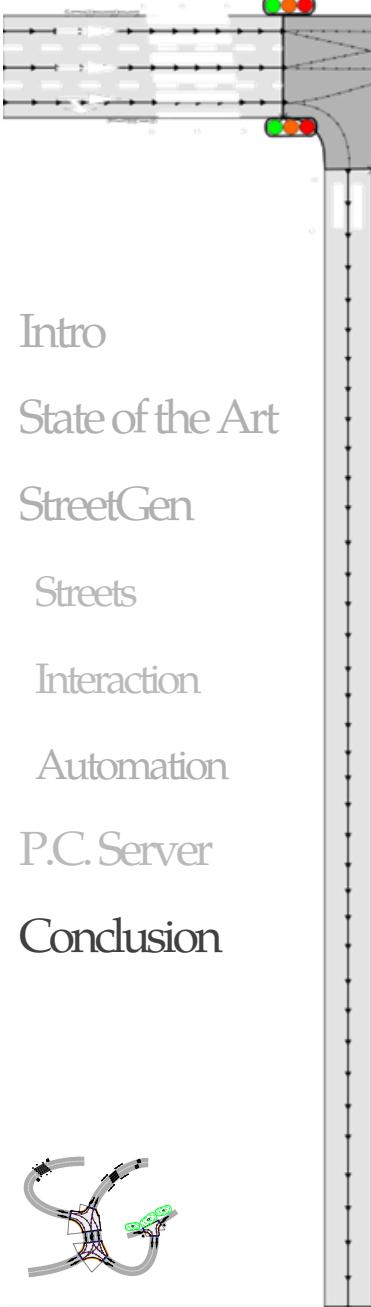
Summary

Limitations

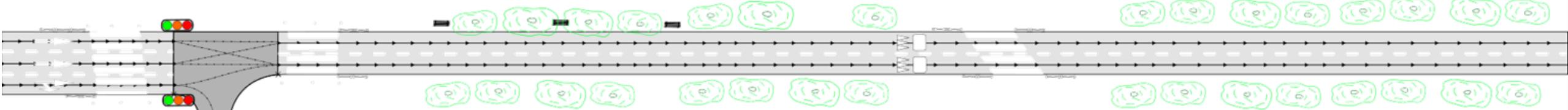
Perspectives



Conclusion: Limitations



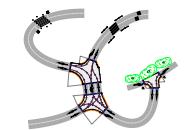
- StreetGen
 - Model too simple
 - Interaction limited to simple mechanisms
 - Optimise only a part of the model
- Point Cloud Server :
 - Must group points into meaningful groups
- Objects are created/edited manually by user
 - Tedious, not much sense



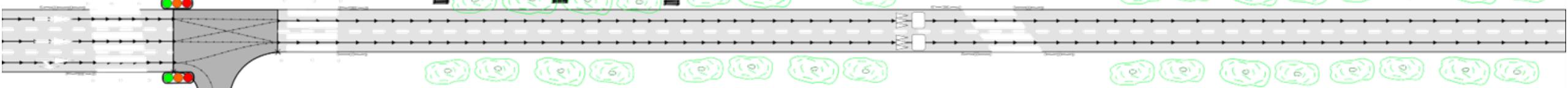
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Conclusion: Perspectives



- Only the beginning of inverse procedural street modelling.

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

im

im

Conclusion: Perspectives

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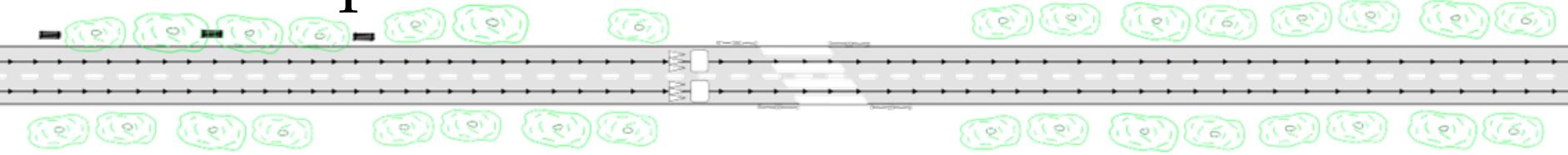
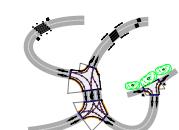
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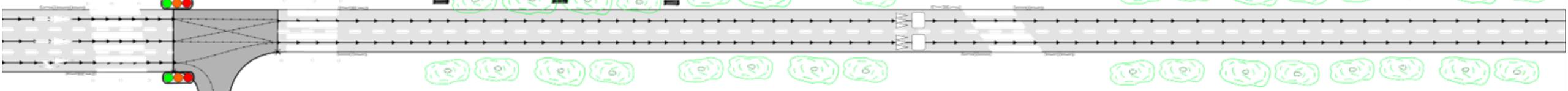


- Major trend in smart vehicle/autonomous cars
 - → maps potentially required by every (Billion) cars
- For the moment: low level information, but
 - All cars will need a shared high level road model

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Conclusion: Perspectives

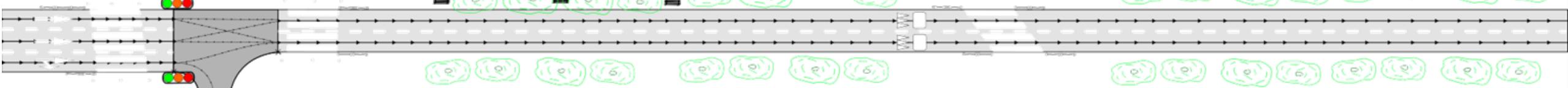


- Cities are evolving
 - There are several cities in one city:
 - Café terrace: day/night
 - Garbage bin
 - (parking behaviour)
 - Time is essential (simulation/understanding)
 - 4D street modelling ?

im

im

Conclusion: Perspectives



- To understand city evolutions → study city history
- Historical geodata
 - Hand drawn maps
 - Information needs to be extracted
 - (my current work)

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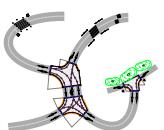
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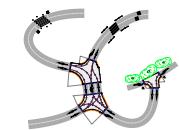


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Conclusion: Perspectives

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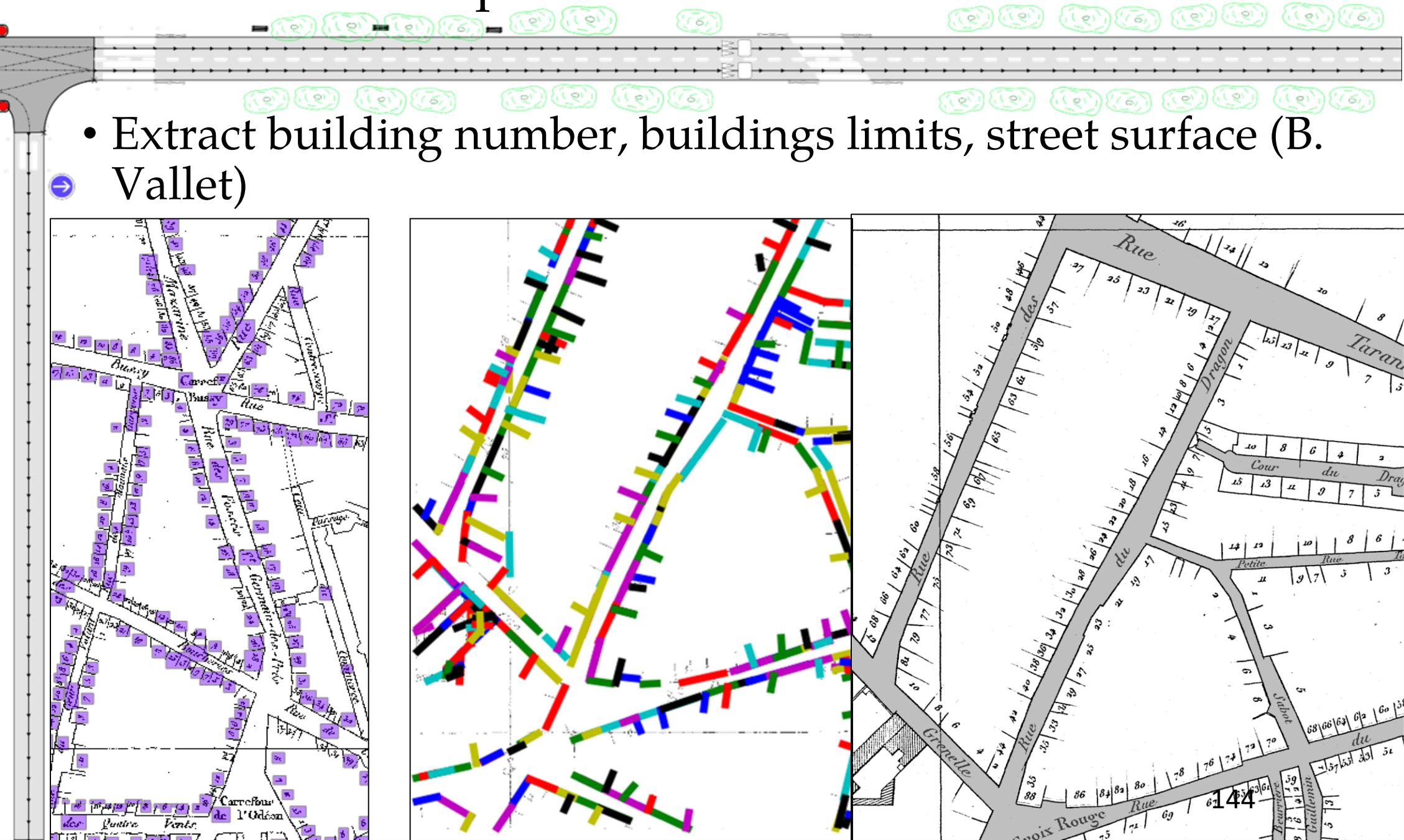


- Jacoubet,
1810-1836 :
- road model
with
optimisation
& Streetgen
?



Conclusion: Perspectives

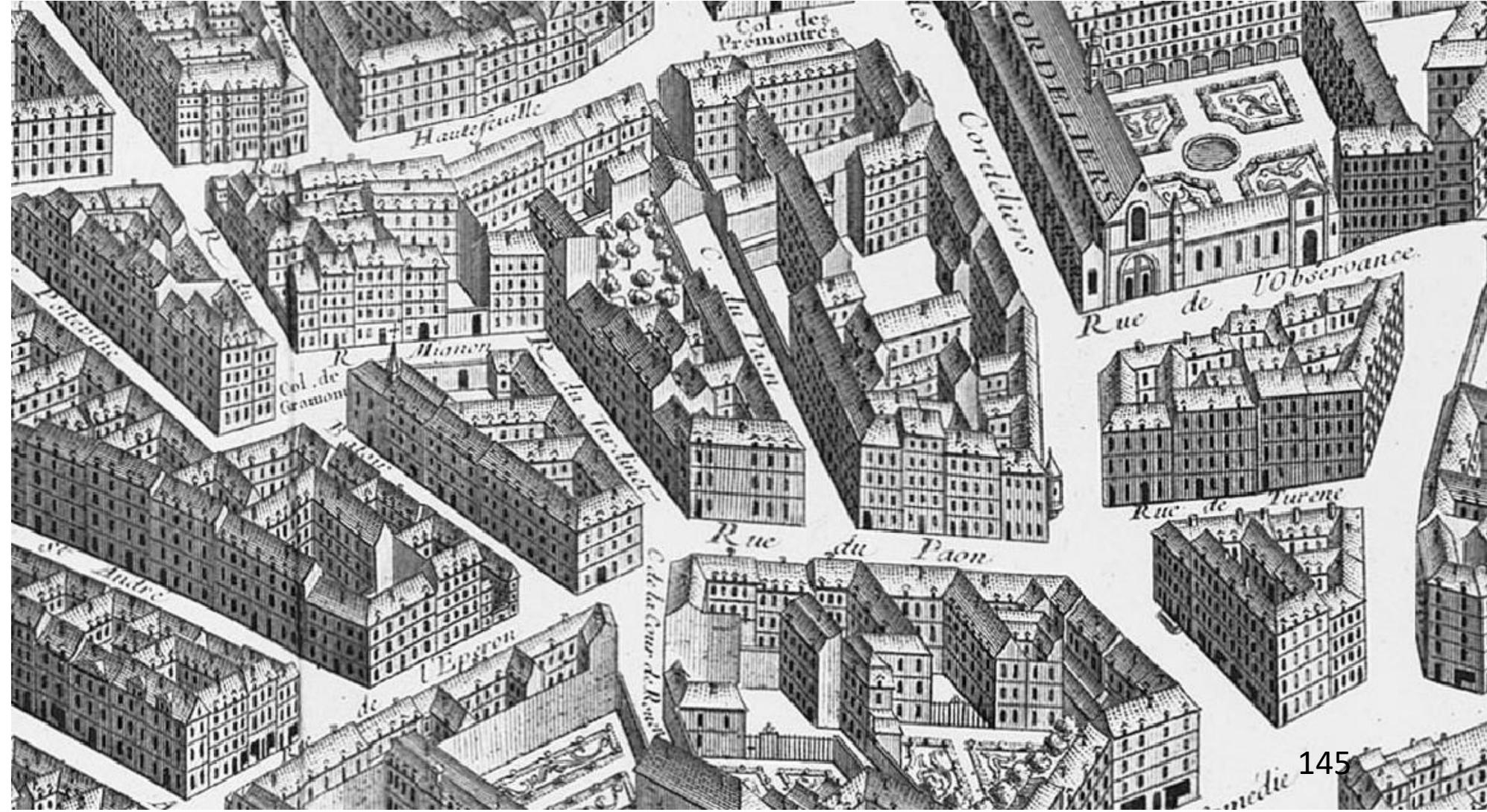
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- Extract building number, buildings limits, street surface (B. Vallet)

Conclusion: Perspectives

- Turgot, 1734-1739 : isometric persp.



QUESTIONS

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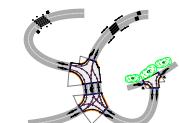
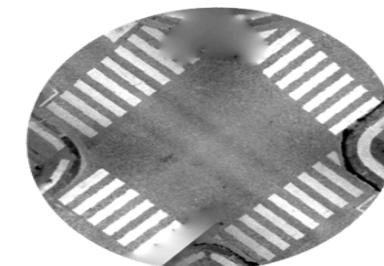
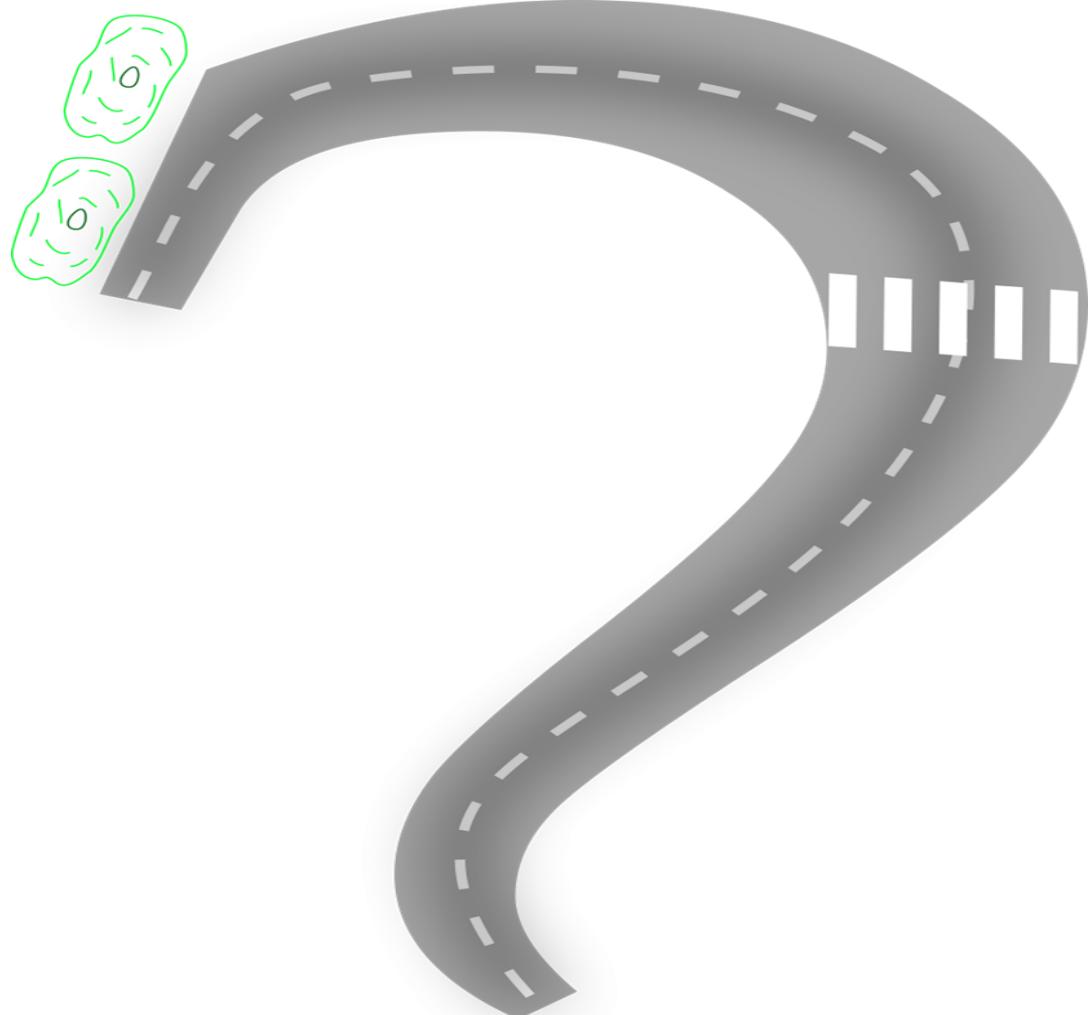
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TODO

- 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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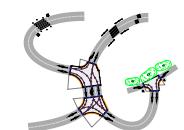
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- - le besoin de mieux expliquer la démarche générale et de la rappeler avant chaque partie
- - le besoin d'ajouter des contributions à la fin de chaque chapitre
- - une réécriture des limitations pour être plus cohérentes
- - le besoin de réduire l'information pour pouvoir passer plus de temps à expliquer certains schémas
- - le besoin de fluidifier certaines transitions (notamment la transition nécessaire vu que le Point Cloud Server se retrouve à la fin)



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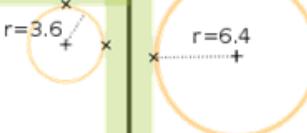
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appendix

annexe

StreetGen : Kinematic hypothesis

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 ...

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Todo bonus: schema XML

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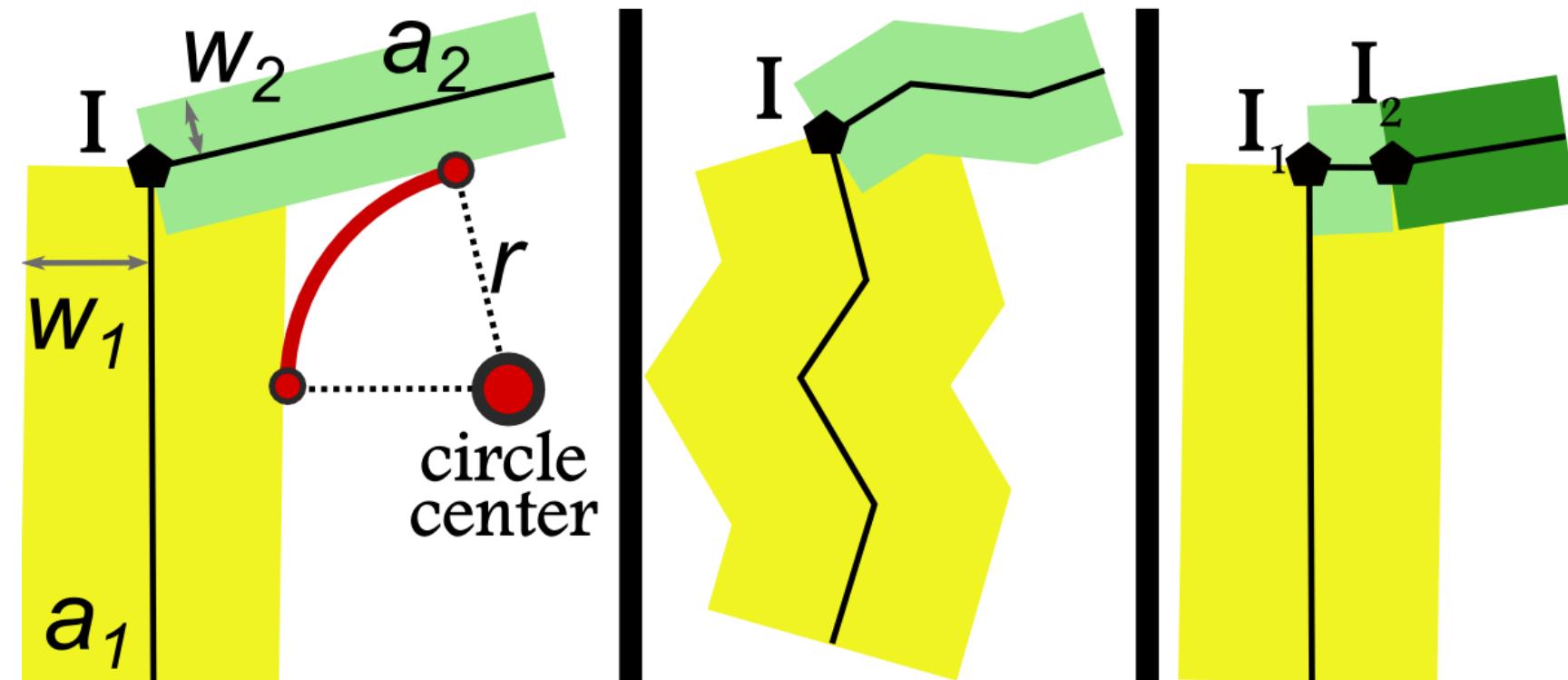
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- We have road axis, road width
 - How to compute circle center and arcs?
 - ~~analytical computing (vector, angle) ?~~



Point Cloud Server: Method

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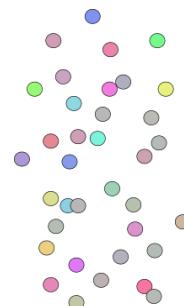
P.C. Server

Conclusion

- 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

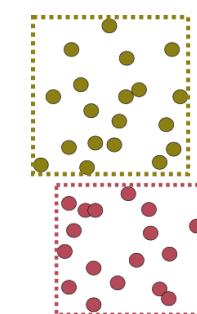
1 row = 1 point
Analogy : Pixels



Billions
points



1 row = N points
Analogy : Image

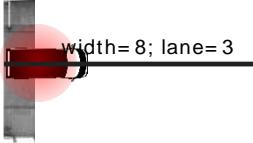


Million
groups

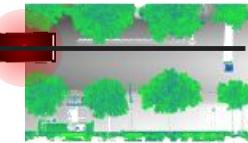


Usage : do we really need
to get points 1 by 1?





Point Cloud Server: Loading/Exporting



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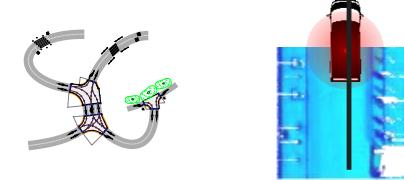
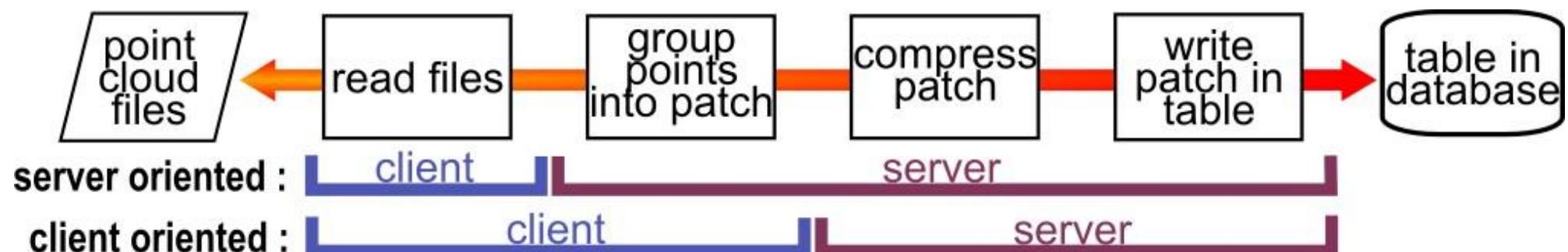
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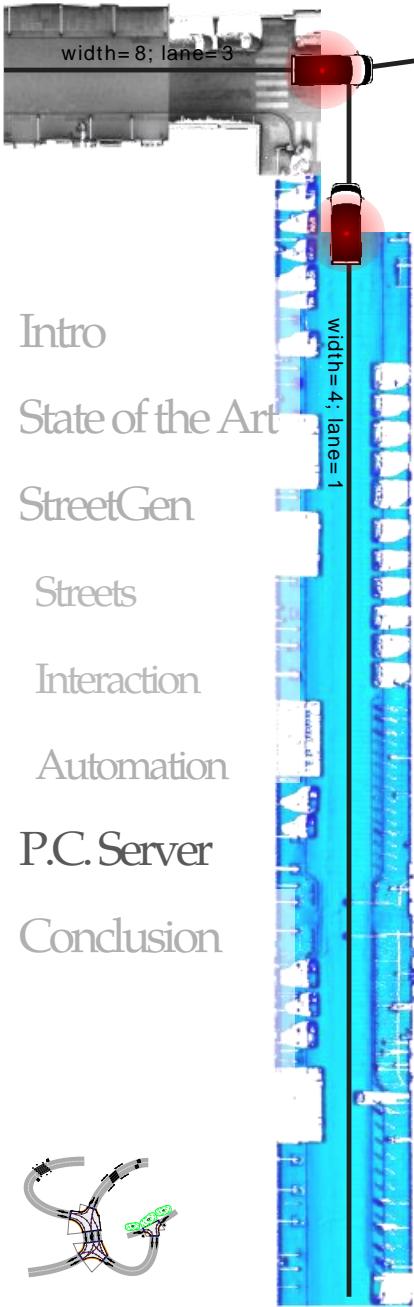
P.C. Server

Conclusion

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

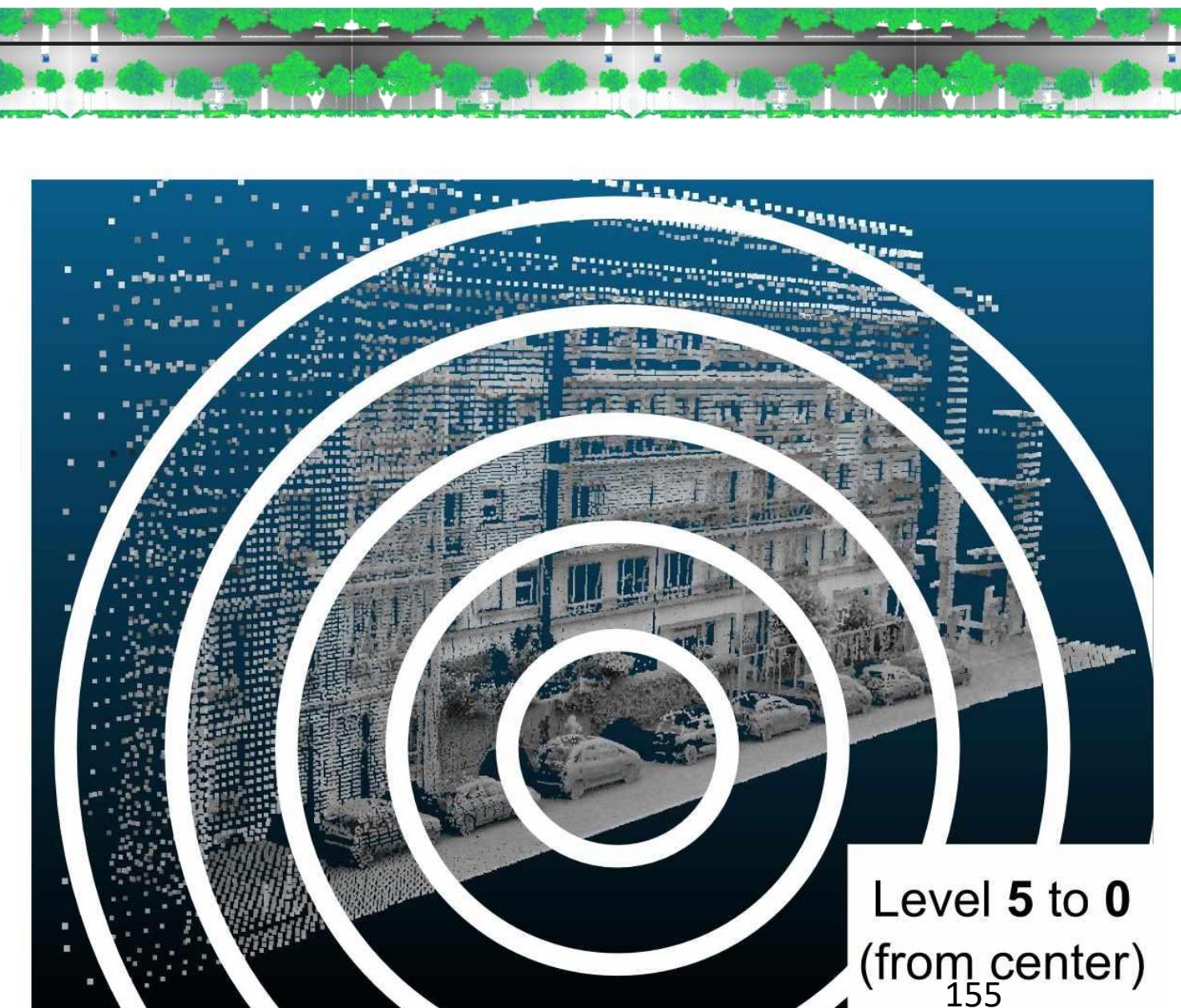


Point Cloud Server: Level Of Detail



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- For visualization, LOD depends on distance to camera



Level 5 to 0
(from center)
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