

Geometius: De dag van de puntenwolk

Point Clouds: direct and explorative use

Edward Verbree, Martijn Meijers, Peter van Oosterom

TU Delft, Section GIS-technology

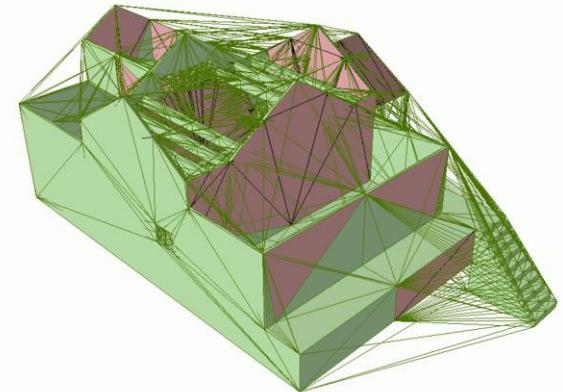
26-03-2019 De Kalkovens, Huizen



Edward Verbree

Sectie-GISt TU Delft

- Onderzoeksthema's
 - Voorheen (tot 2010):
 - 2D/3D Conforming Delaunay Triangulations / Tetrahedralizations
 - Nu (vanaf 2010 ...)
 - Puntenwolken "as is"



Doe~~l~~ presentatie: Puntenwolken “as is”

- Direct gebruik van puntenwolken
- Exploratieve zeggingskracht van puntenwolken
- Presentatie op basis van:
 - Eerder verricht onderzoek, (conference) papers
 - Projecten en (afstudeer)studies MSc Geomatics en MSc GIMA
 - Twitter (!) / LinkedIn / Peter R. de Vries / Monty Python
 - OGC – Pointcloud DWG
 - Samenwerkingsverband Rijkswaterstaat
- Slides / Dia's: Engels / Nederlands

Wat denk je hiervan?

Edward Verbree likes this

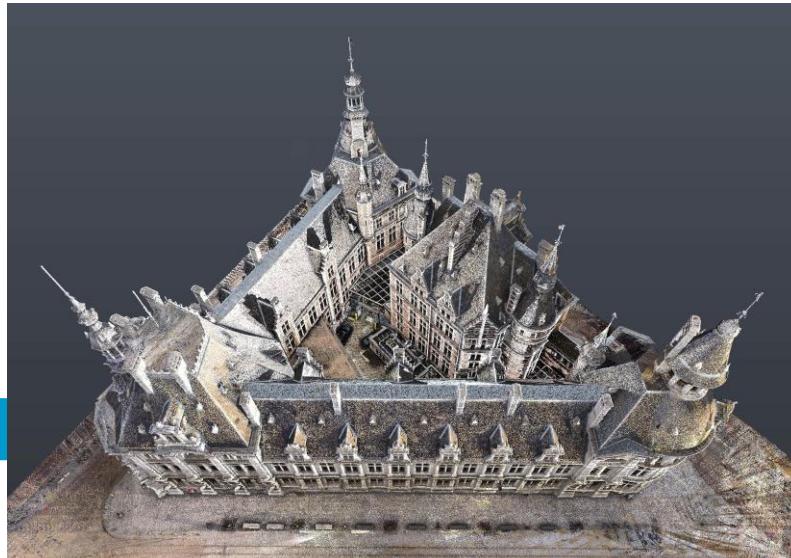
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Nic Kerkhof • 2nd

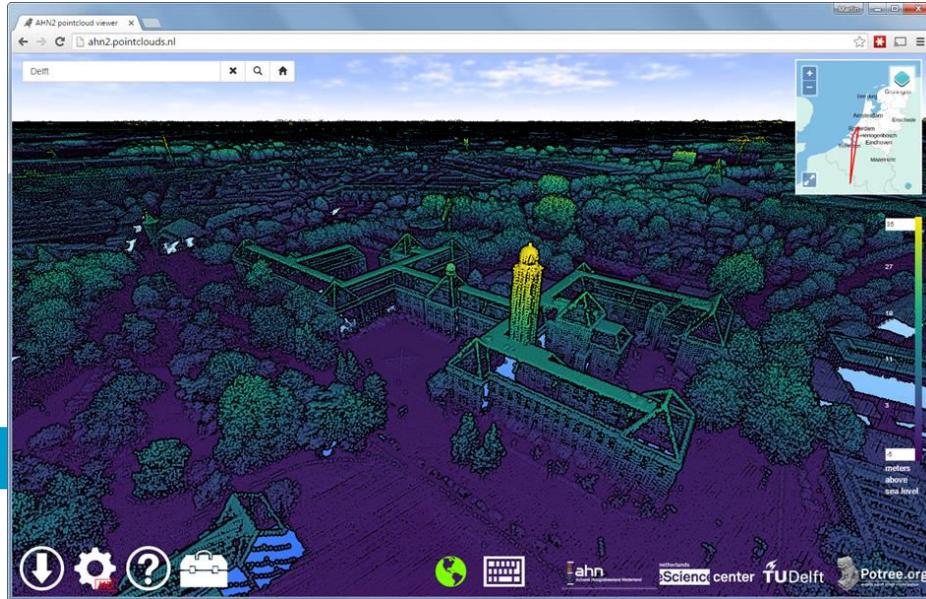
N² Kwadraat - 3D laserscanning - indoor & outdoor 3D metingen
1d

3D opmeting/scanning van het prachtig historisch gebouw Nationale Bank te Antwerpen. Het exterieur en interieur werd vastgelegd in 920 scanposities met onze Faro S150 en S350. Er werd gebruik gemaakt van de innovatieve SCAN PLAN als interne gps. Momenteel wordt de point cloud uitgewerkt tot een Revit BIM model, 2D CAD-plannen en een 3D printbare stl-file. **#N2Kwadraat #NX2 #SCANtoBIM #3Dscanning #BIM #Revit #Faro #Architecture #Antwerpen**



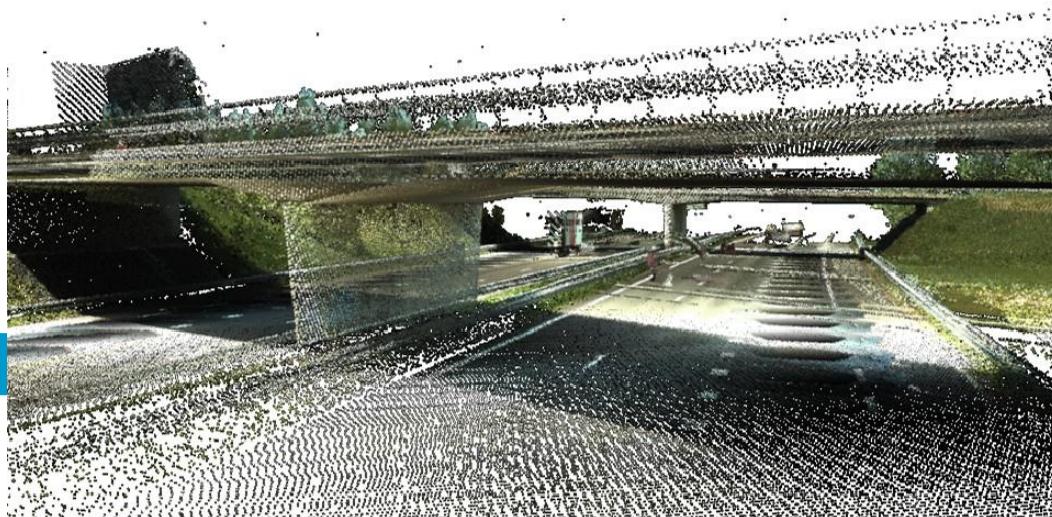
Outline

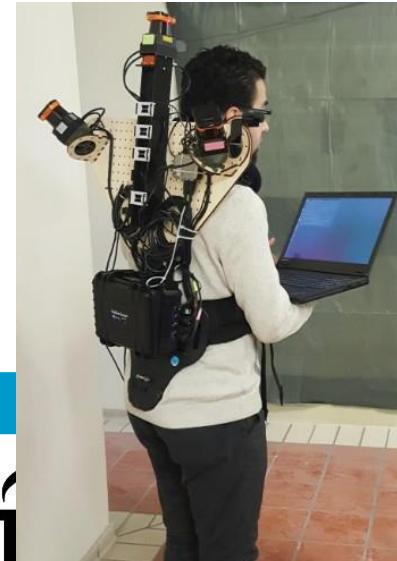
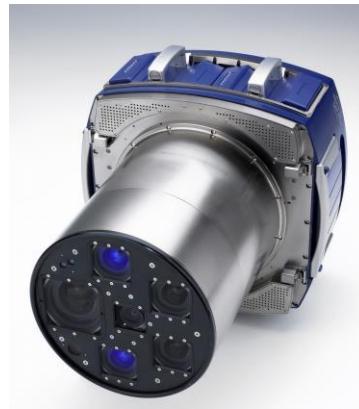
- Potential of Point Cloud data
- Modelling the World
- Point Clouds as core data source
- Immediate Use and Analysis



3D/nD Point Clouds Geometry + Attributes

- Unstructured set of points in 3D space
- Unorganized structure, no hierarchy
- Accurate, but discrete, representation of surfaces
- Base data for 3D representation

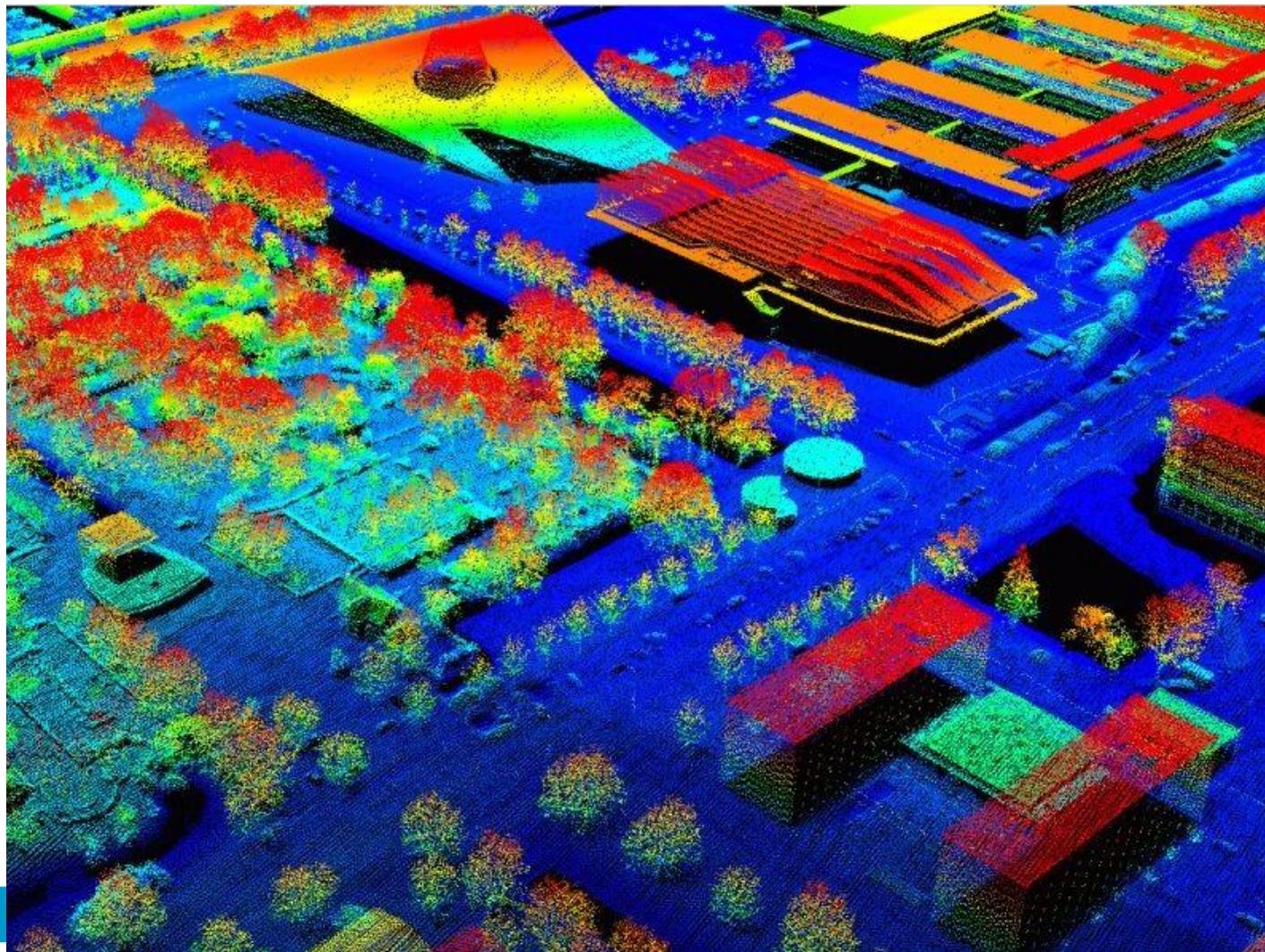




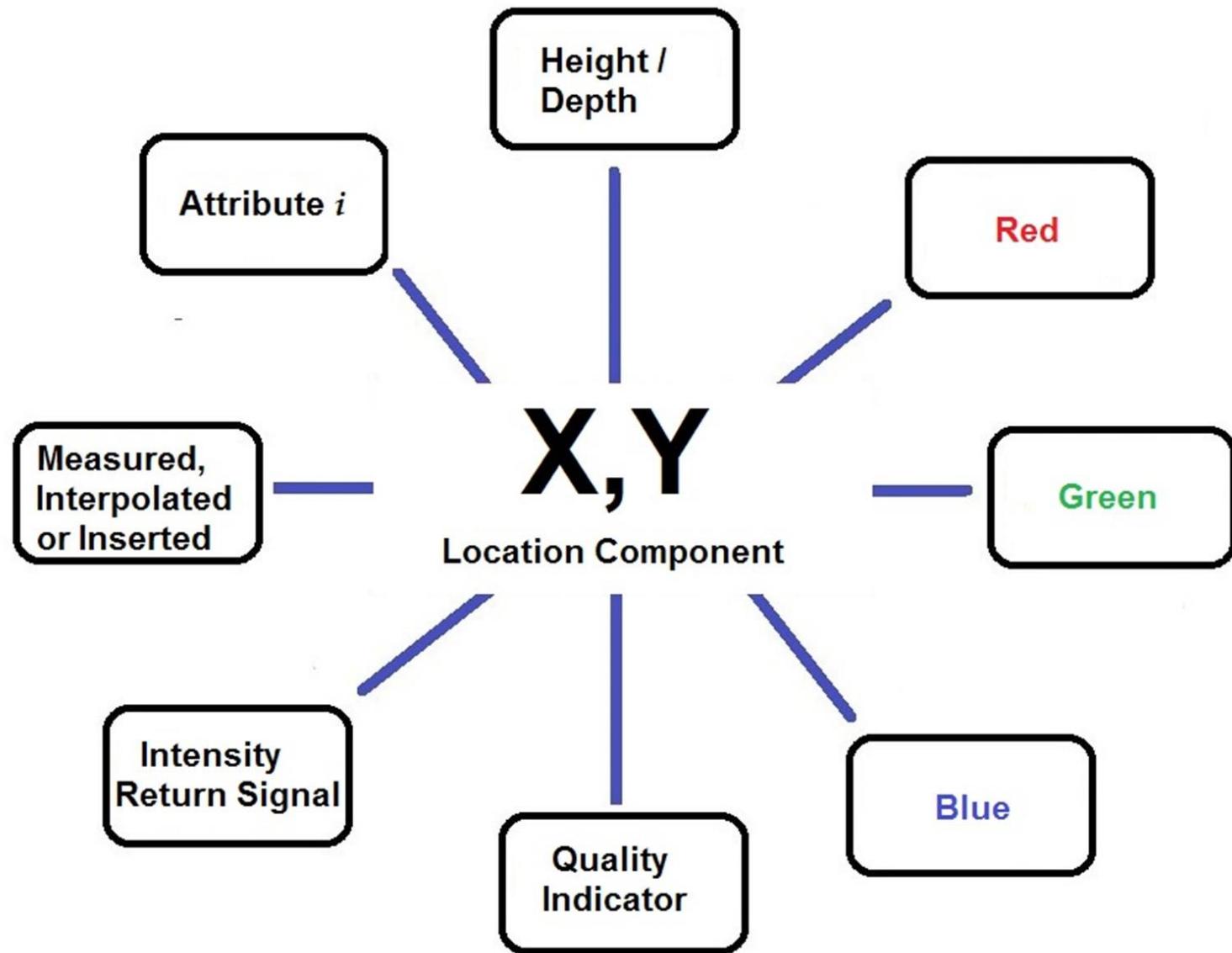
Where do point clouds come from?

- Laser scanning – LIDAR (LIght Detection And Ranging)
 - Airborne
 - Mobile/Terrestrial
- Photogrammetry
 - Dense image matching
- Bathymetry
 - Multi-Beam Echo Sounding
- Consumer hardware
 - Kinect
 - Swiss ranger (depth camera)

Technology that shapes our society



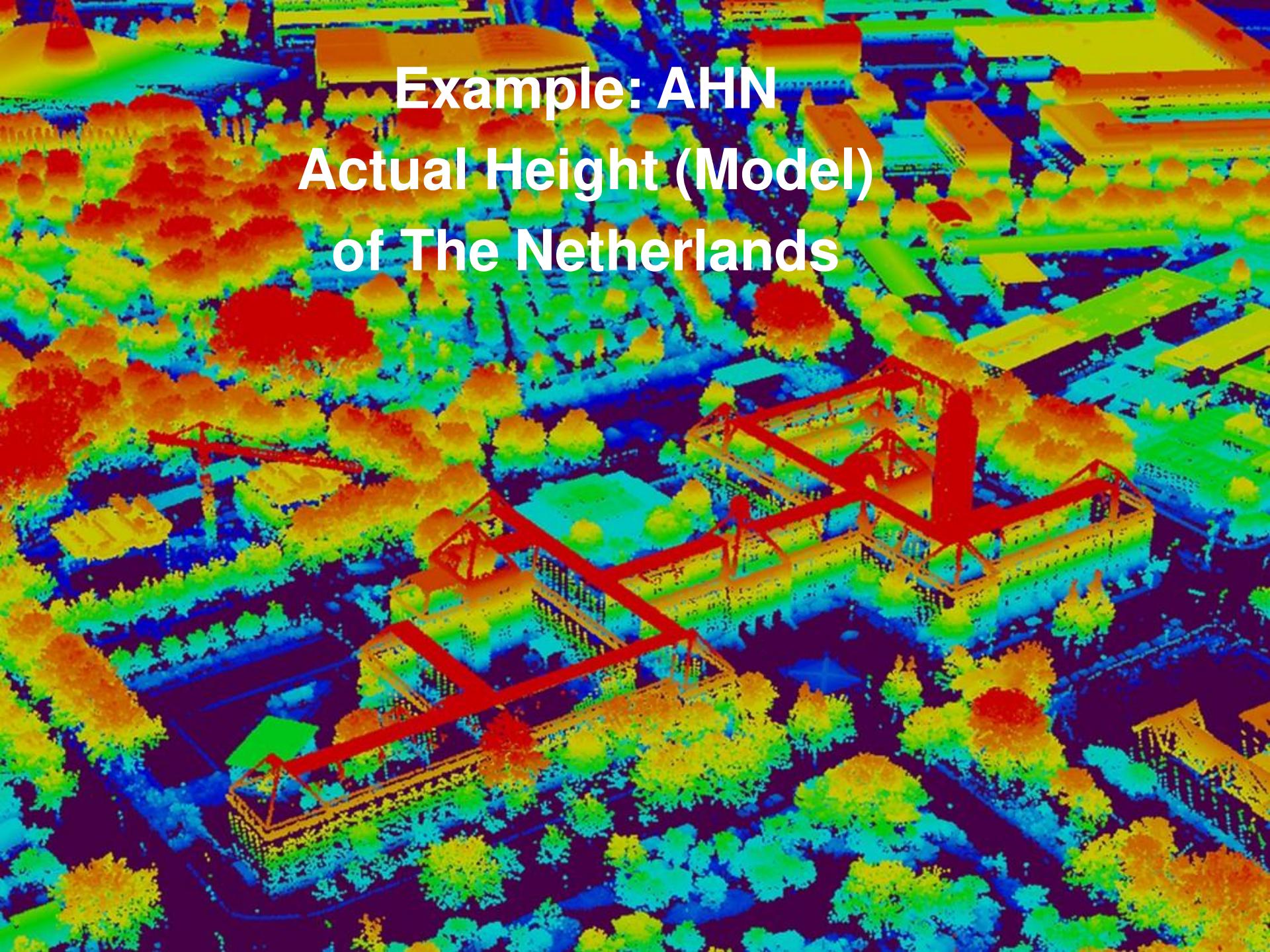
Nucleus of Point Clouds



Point Clouds information

[After: Point Cloud Acquisition & Structuring, Presentation by Fabio Remondino, 2018]

- Not only geometry, but also attributes
 - Photogrammetry
 - RGB
 - Uncertainty
 - Redundancy
 - Intersection angles
 - Classes
 - Normals
 - Lidar
 - Intensity
 - Number of returns
 - GPS Time
 - Strip
 - Classes
 - Normals / Scan Angle

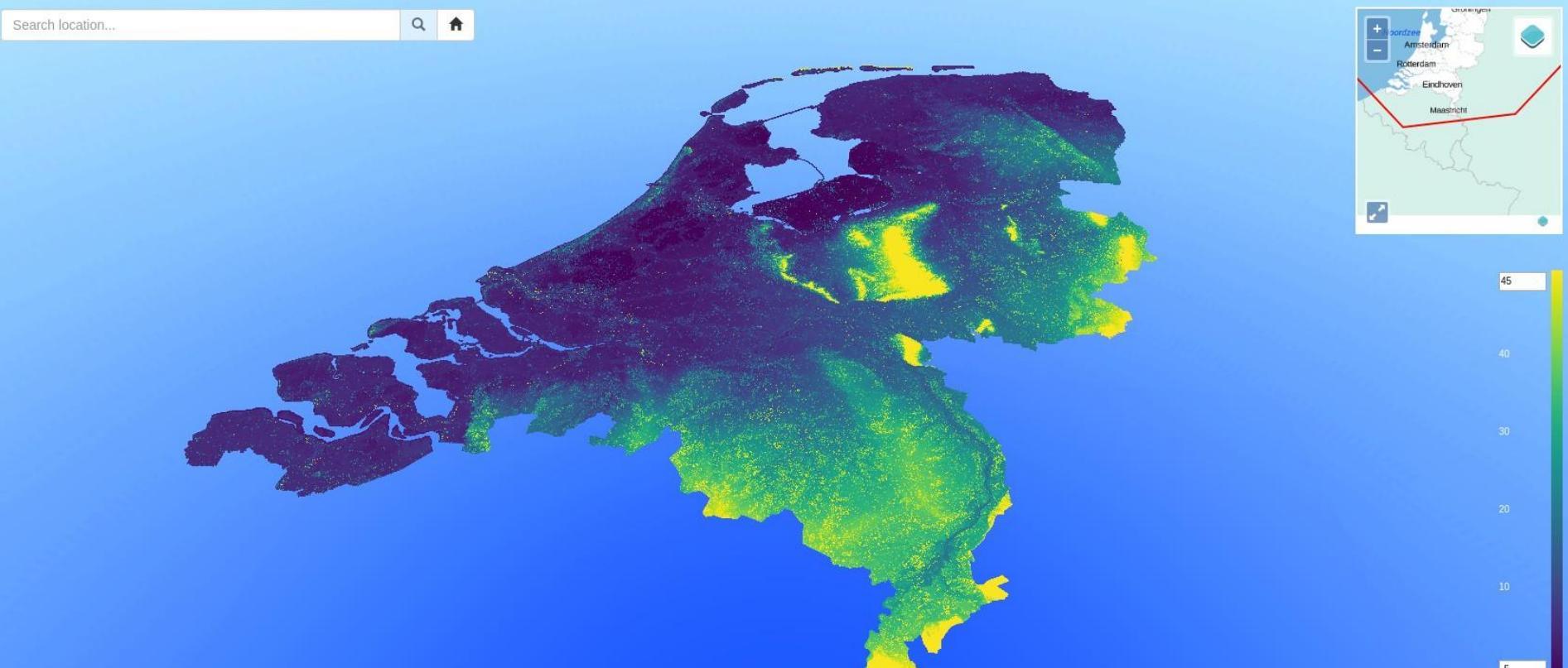
An aerial view of a rural area in The Netherlands, showing fields, trees, and several large agricultural buildings. The buildings are highlighted with a thick red outline, emphasizing them against the colorful terrain. The terrain is rendered in a gradient of green, yellow, and orange, indicating elevation or height. The buildings themselves are mostly white with blue roofs.

Example: AHN Actual Height (Model) of The Netherlands

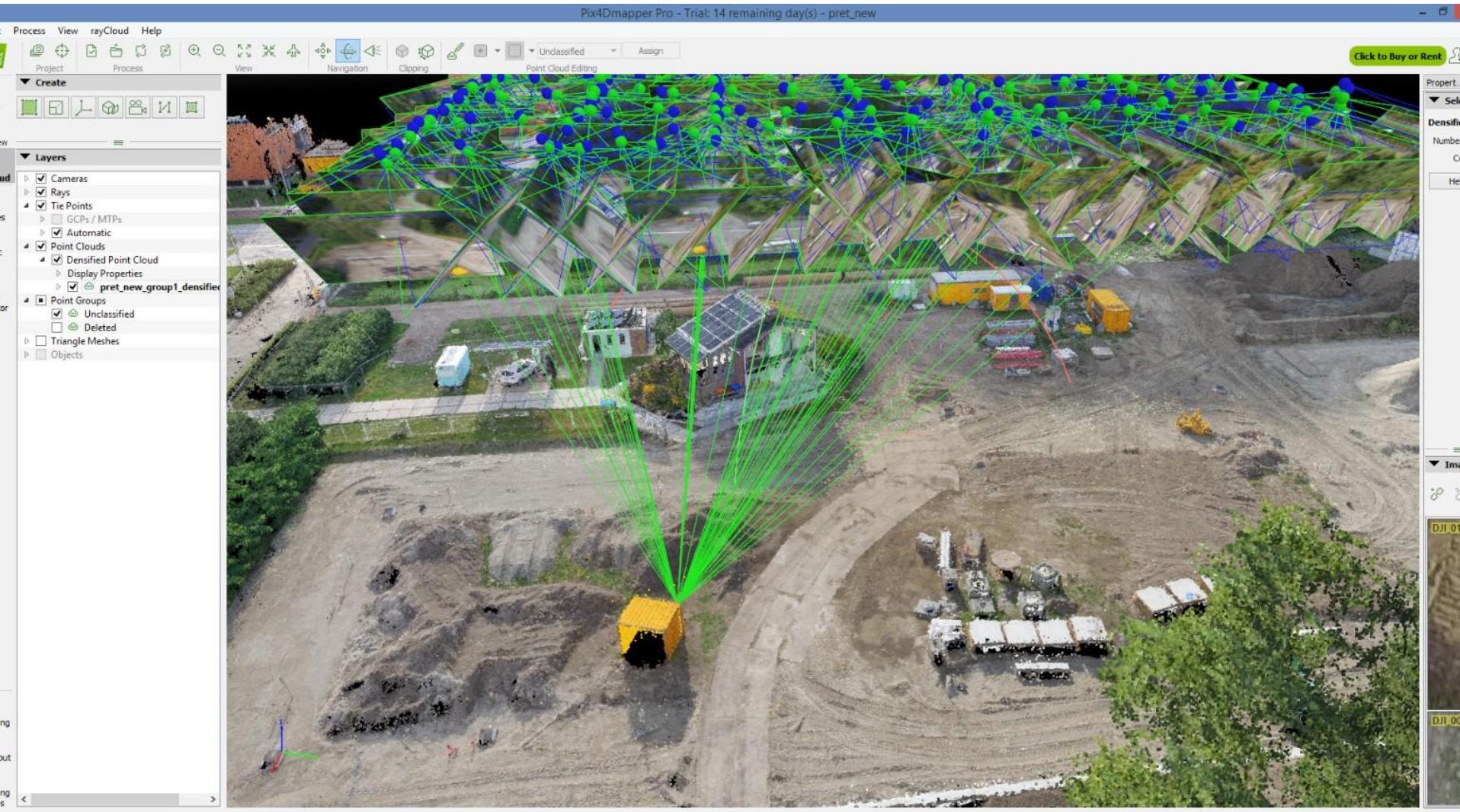
NL eScience Point Cloud project

<http://pointclouds.nl/>

<http://potree.entwine.io/data/ahn.html>



Create your own Point Cloud Here, there and everywhere



Point Clouds and Smart Cities

ABOUT THE AUTHOR



Mathias Lemmens is an international consultant and the author of the book *Geo-information – Technologies, Applications and the Environment*. He lectures on geodata acquisition technologies and data quality at Delft University of Technology, The Netherlands, where he is education director for the MSc Geomatics for the Built Environment.

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The 'smart city' concept entirely relies on a permanent stream of massive amounts of data acquired by a great variety of sensors distributed throughout the city. Smart use of all this data requires integration with 3D city maps for which point clouds, acquired by laser scanning or photogrammetry, are the main sources. The author of this article identifies the abilities of point clouds to support the smart city concept.

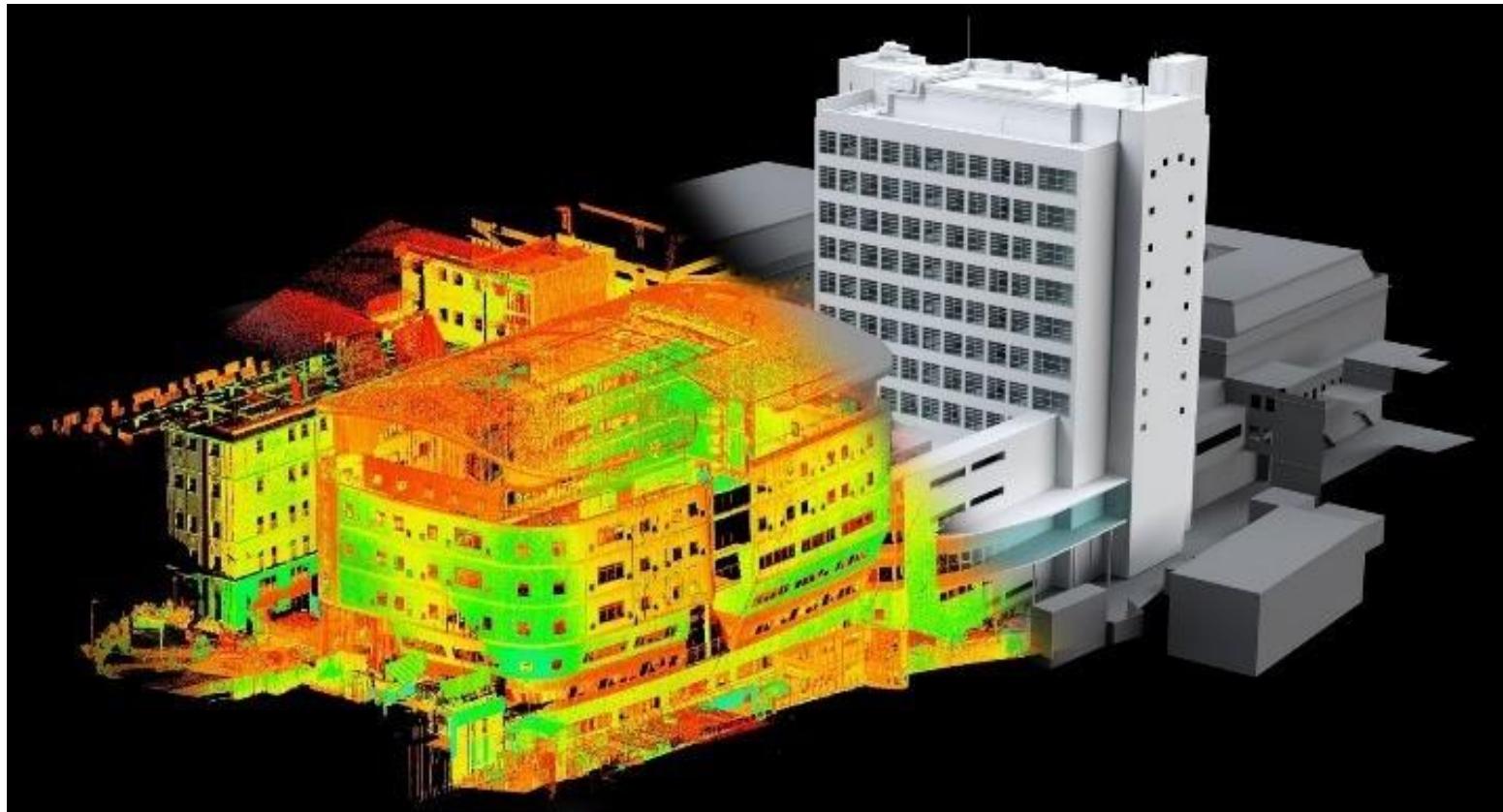


▲ Figure 9: Green village sustainable building on Delft University of Technology campus, imaged from a UAS.



▲ Figure 4: 3D map at LoD1 of a part of Rotterdam automatically created by combining building footprints with airborne Lidar point clouds (source: Municipality of Rotterdam).

Create 3D models for use in BIM/CAD



Modelling the World in 3D: Processing takes time and money

- Example: 3D TOP10NL of the Netherlands
 - 640.000.000.000 AHN2 height points (2008-2011)
 - 15.000.000 TOP10NL objects (2012-2014)
- Fast processing, some super computer power
 - Integration of two (distinct) data sources



Gebouwhoogte van Nederland

<https://apps.webmapper.nl/gebouwen/#14.06/51.9104/4.4961/0/57>



Rotterdam-3D:

3D BGT, 3D BAG en 3D BOR in één beeld.

- "Met behulp van 3dfier is de BGT van het centrum van Rotterdam binnen 10 minuten in 3D opgewerkt. De stap naar een 3D BGT van heel Rotterdam is dichtbij. Samen met onder andere gebouwen en bomen begint het 3D stadsmodel op basis van diverse georegistraties al aardig volledig te ogen."
- Verder vorm? Of vooral heel veel nietszeggende facades?



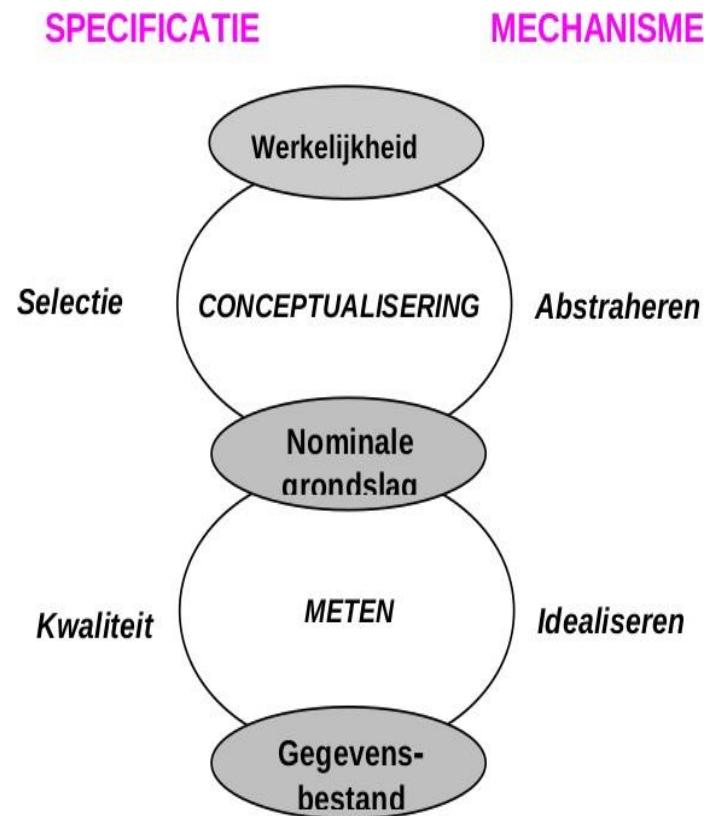
GeoCraft: Veel veelzeggende façades

<https://geocraft.nl/>



Modelling the World Quality: Universe of Discourse

- First step:
 - “Ideal” Conceptualisation
- Second step:
 - “Ideal” Measuring and Capturing
- Universe of Discourse:
 - What should have been produced
 - According to predefined standards and information models



Vision: Explorative Point Clouds from Sequence to Integration

- Sequence:
 - Acquisition → Modelling → Application
- Integration:
 - Acquisition → Immediate Use → Application

Potential of Point Cloud Data

- Decision making processes
- Many expert-users from different professions
- Strong urge to access the original measured data
- Interactive Visualisation
- Analysis tools

Potential of Point Cloud Data

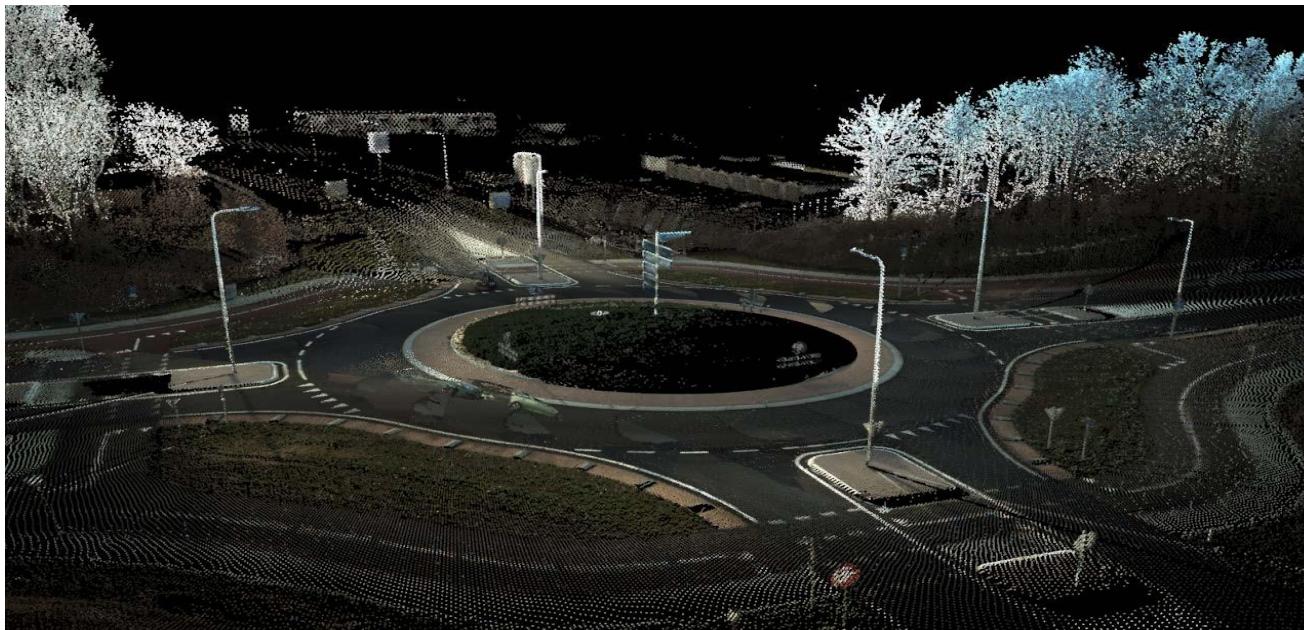
Rodney Brooks, 1990, Elephants don't play chess

[https://doi.org/10.1016/S0921-8890\(05\)80025-9](https://doi.org/10.1016/S0921-8890(05)80025-9)

- The key observation is that the world is its own best model. It is always exactly up to date. It always contains every detail there is to be known. The trick is to sense it appropriately and often enough.

Modelling the World: Statement

- Point Clouds have more value than the (derived) traditional 2D maps / 3D models



Rutger Kopland

De Landmeter (1982)

Het is niet alleen onverschilligheid, in zekere zin
is het misschien zelfs wel liefde die hem dwingt,
er is geen paradijs zonder rentmeester.

Hij is gelukkig met het landschap, maar gelukkig
met het zoeken, coördinaten wijzen hem zijn onzichtbare
plek, zijn utopie is de kaart, niet de wereld.

Hij wil weten waar hij is, maar zijn troost is
te weten dat de plek waar hij is niet anders bestaat
dan als zijn eigen formule, hij is een gat in de vorm van
een man in het landschap. **Met de grenzen die hij
trekt, scherper en duidelijker, vervagen het gras
en de bomen en alles wat daar leeft, lijdt en sterft.**

Het is heel helder om hem heen, alles is waargenomen.

Rutger Kopland

The Surveyor

(Translation: James Brockway, 2001)

It isn't mere indifference, in a certain sense
it is perhaps even love that drives him on,
there's no paradise without its steward.

He is happy with his landscape, but even happier
with searching, co-ordinates point him to his invisible
spot, the map, not the world, is his Utopia.

He wants to know where he is, but it's his consolation
to know that the spot where he is standing exists only
as his private formula, he is a hole in the shape of
a man in the landscape. **With the boundaries that he draws,**
sharper, more distinct, the grass and the trees grow
vaguer and everything that lives, declines and dies.

The world around him is perfectly clear, everything has been observed.

“Every time I walked through I found something I have not seen before”

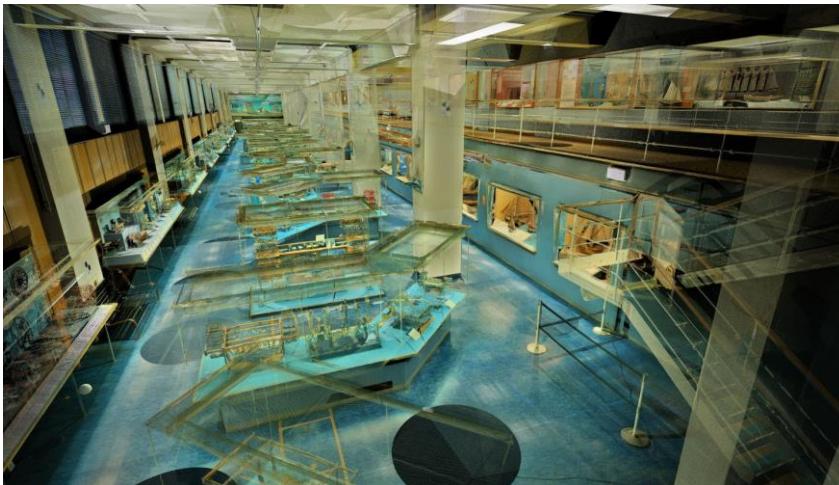
Science Museum - The Shipping Galleries – 1963 – 2012

A digital 3D Archive <http://youtu.be/gDTbFhFZl9I>



Science Museum

- “Who did ever imagine in 1963 that we could make a virtual shipping gallery out of lasers and computers [...] I can't wait to see how this technology develops”
- These guys have made a time machine...”



In the eyes of the animal

<http://iteota.com/experience/welcome-to-the-forest>



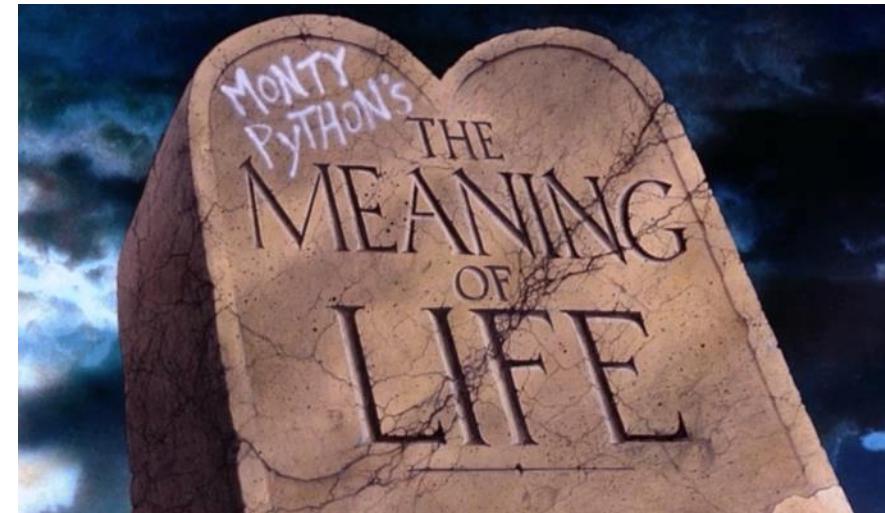
Direct and Exploratory Use of Point Clouds

- Point Clouds keep the details
- Added value to be revealed by user



Monty Python – The Meaning of Life

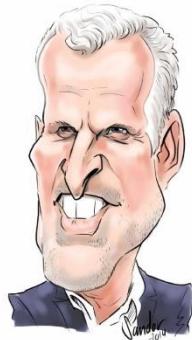
- Every sperm point is wanted
Every sperm point is good
Every sperm point is needed
In your neighbourhood



Serie “Judas”

Peter R. de Vries ≠ Ronald Top

<https://dewerelddraaitdoor.bnnvara.nl/media/682373>



- “Dat zo’n serie voor mij eigenlijk een karikatuur wordt ... Weet je wat het punt is: ze proberen juist - en dat is eigenlijk het probleem - ze proberen het heel precies na te doen en daardoor ga je juist de verschillen zien.”



Explore – Explorative

<https://en.oxforddictionaries.com/definition/explore>

- Travel through (an unfamiliar area) in order to learn about it.
 - 'the company has been granted licences to explore for petroleum'
- Inquire into or discuss (a subject) in detail.
 - 'he sets out to explore fundamental questions'
- Examine by touch.
 - 'her fingers explored his hair'

Eliminate Modelling Step: Point Clouds as an authentic source

- While sensor technology develops, the amount of data we acquire increases rapidly, approaching near real time observations
- Data is increasingly needed for decision making in smart systems
- The intermediate modelling step becomes a bottleneck
- Expensive: money-wise & time-wise

Modelling the world by Point Clouds: The challenge

- Data acquisition systems produce much more data than before
 - Point Clouds and Images
- Reduction in hardware cost leads to higher frequency (more often) and shorter data collection time
- Projects require sensor data fusion
- Raw point data becomes the authentic source
- Traditional maps or models become derivatives, preferably computed on demand

Managing nD-PointClouds

- Peter van Oosterom, Martijn Meijers, Edward Verbree, Haicheng Liu, Theo Tijssen, Towards a relational database Space Filling Curve (SFC) interface specification for managing nD-PointClouds, In: Geoinformationssysteme 2019, Beiträge zur 6. Münchner GI-Runde (Thomas Kolbe, Ralf Bill, Andreas Donaubauer, eds.), München, pp. 61-71, 2019.

Towards a relational database Space Filling Curve (SFC) interface specification for managing nD-PointClouds

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Abstract

In this paper we propose to treat point clouds as a first-class representation (similar to vector or raster representations), with the nD-PointCloud as the solution for this, offering deep integration of space, time and scale. For efficiency reasons spatial indexing and clustering of these large point clouds is extremely important and this is obtained based on a Space Filling Curved (SFC). In order to get beyond the current state of the art of storing/ managing point clouds in files, a DBMS solution is presented (with all benefits: integration with other data types, scalability, multi-user, transaction support, etc.). Finally, a DBMS SFC interface specification for point clouds is proposed.

Rich point clouds in virtual globes – A new paradigm in city modeling?

From: Nebiker et al. (2010)

<http://dx.doi.org/10.1016/j.compenvurbsys.2010.05.002>

Table 1

Comparison of 3D city modeling paradigms.

Characteristics	Modeling Paradigm		
	Geometric 3D modeling	Image-based modeling	Rich point cloud based modeling
Modeling concepts	Geometric 3D models based on boundary representations, parametric models or procedural approaches	Urban environment represented by geo-referenced imagery (panoramic mosaics or image collections)	3D urban environment represented by 3D point clouds with rich geometric, radiometric & semantic properties
Representation modeling	Photo-realistic texture maps (reality-based or generic)/cartographic representation models	Zoomable, pannable 2D images linked in a spatial structure	Texturing of 3D point clouds with visible or non-visible properties (NIR, thermal IR)
Modeling strategy	Explicit modeling (3D object generation) at the beginning of the process chain	Automated generation of panoramic image mosaics or co-registration of image collections	Immediate and direct use of 3D point clouds /classification & object extraction as and when needed
Prevailing acquisition strategy and coverage	Airborne laser scanning and imaging/full area coverage	Ground-based mobile mapping (panoramic models)/along road networks & hotspots	Ground-based mobile laser scanning/along road networks
Geo-referencing accuracy requirements	Medium to high	Medium to low (GPS position & azimuth or simple geo-tagging)	High (GNSS & INS)
Modeling scope	Macro-to meso-scale /primarily buildings and terrain	Meso- (to micro-) scale /anything visible	Micro- to meso-scale /high fidelity representation of immediate surrounding
Suitable visualization scenarios	Fly-through/bird's eye perspective	Stepwise drive- and walk-through	Continuous drive-through and walk-through
Navigability and camera orientation	Free navigability and camera orientation	Free panning & zooming, navigation constrained to image acquisition positions	Free camera motion and navigability but preferably along acquisition tracks (touring)
Use cases/scenarios (selection only)	3D GIS, urban planning (macro- to meso-scale), marketing, tourism, flight simulation	Location-based services (LBS), tourism, fun, road infrastructure management	Driving simulation, road infrastructure management, urban planning (micro- to meso-scale)

Explorative Point Cloud Challenges

- Adaptive object recognition
 - How to move away from static single-purpose object recognition?
- Visualisation & Dissemination
 - How to get the valuable point clouds to real users?
 - How to make sure they understand these point clouds?
- Data Fusion
 - How to combine Point Clouds with existing data?
- Analysis directly using Point Clouds
 - Not only visualisation: Also analytics

Explorative Point Clouds

Research questions

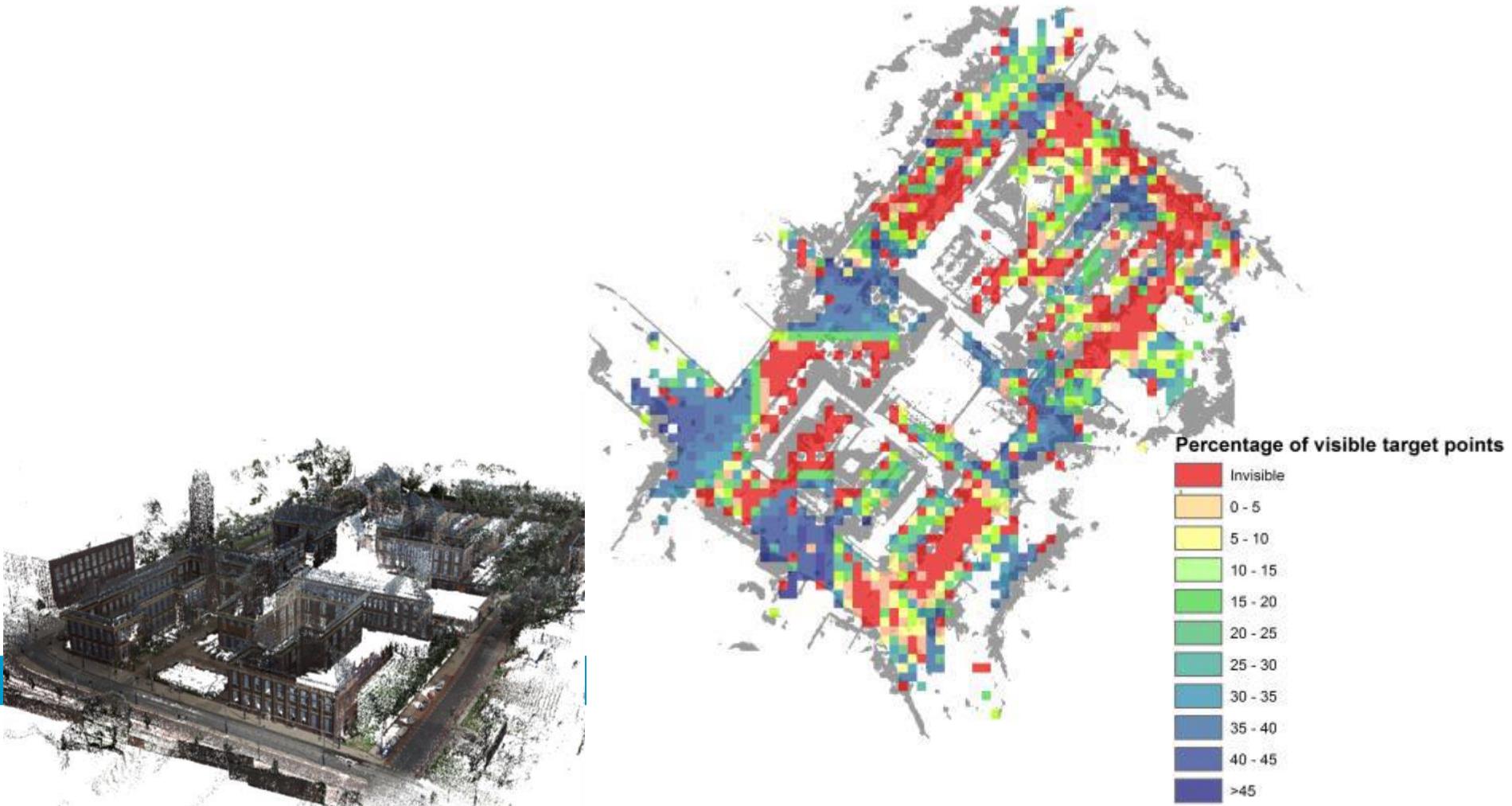
- How do we store, manage and transmit point cloud data to non-specialist users?
- How can we provide interactive visualisation tools, such that point clouds appear for the society (end users) as a virtual world, rather than technical sensor output?
- How can we provide point cloud analysis tools, such as object reconstruction, profiling and change detection?
- What kind of explorative spatial data analysis tools should be available to support domain-experts in extracting semantic information from the point clouds attribute values?

Explorative Point Clouds for Immediate Use and Analysis

- Human Interpretation
 - Visualisation tools and techniques: Cartography (thickness, shape, colour);
- Interactive cartography and Geo-visualisation:
 - Interaction and interfaces;
 - Tools to identify, measure, process, and analyse
 - Visibility analytics: Line of sight;
 - Measurement tools: Length, area, and volume calculations
- Analysis tools:
 - Path-planning, profiles

Visibility Analysis

- Guanting Zhang, Peter van Oosterom, Edward Verbree, **Point Cloud Based Visibility Analysis: first experimental results**, In: Proceedings of the 20th AGILE Conference on Geographic Information Science (Arnold Bregt, Tapani Sarjakoski, Ron van Lammeren, Frans Rip, eds.), Wageningen University & Research, pp. 5, 2017.



Change Detection

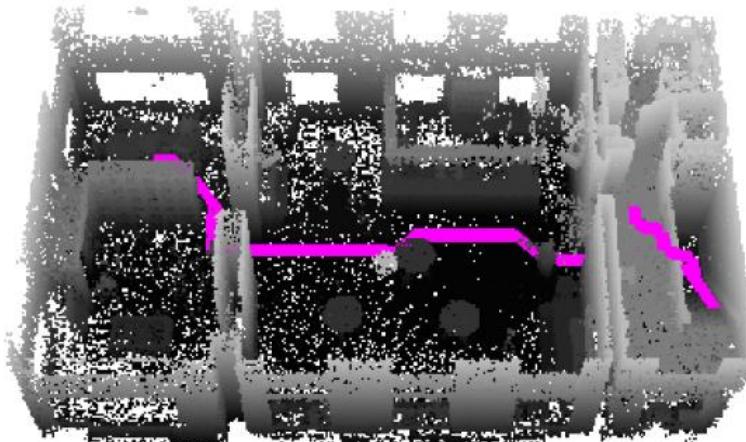
- Barbara Cemellini, Willem van Opstal, Cheng-Kai Wang, Dimitris Xenakis, **Chronocity: Towards an Open Point Cloud Map supporting on-the-fly change detection**, MSc Geomatics synthesis project, Technical report, Delft University of Technology, pp. 78, 2017.



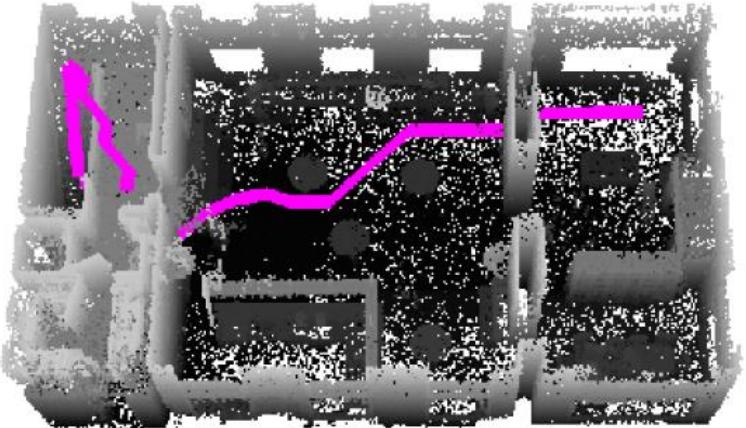
Indoor Routing

- O. Rodenberg, E. Verbree, S. Zlatanova, **Indoor A* Pathfinding through an Octree Representation of a Point Cloud**, Chapter in: ISPRS Annals Volume IV-2/W1, 11th 3D Geoinfo Conference (E. Dimopoulou, P. van Oosterom, eds.), Athens, pp. 249-255, 2016.

Path 1

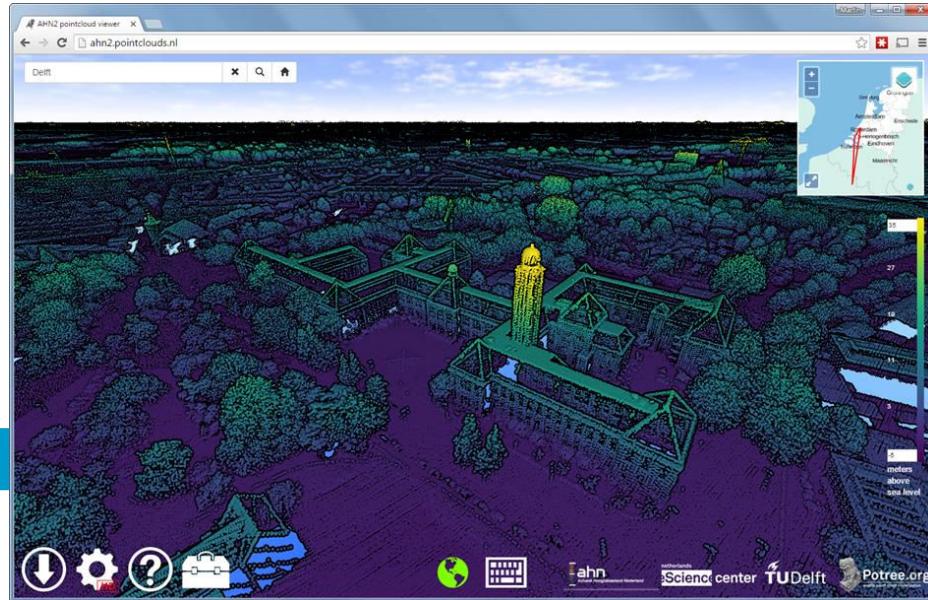


Path 2



Resume

- Potential of Point Cloud data
- Modelling the World
- Point Clouds as core data source
- Immediate Use and Analysis



Questions?

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