Taming the beast: Free and open-source massive point cloud web visualization

Massive Point Clouds for eSciences

http://pointclouds.nl

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netherlands eScience center
by SURF & NWO

TU Delft
Delft University of Technology

Potree.org
webGL point cloud visualization

Netherlands eScience Center

To reinforce and accelerate multi-disciplinary and data-intensive research in the Netherlands by developing and applying eScience and by combining forces.

NWO → netherlands eScience center ← SURF

enhanced Science is about promoting new scientific breakthroughs and innovation by bridging scientific disciplines via ICT

Optimizing Discovery in the Big Data Era

Massive Point Clouds for eSciences

2 year Netherlands eScience research project on massive point clouds

- **TU Delft**:
  - GIS technology
  - TU Delft, Library
  - 3TU.Datacentrum
  - TU Delft Shared Service Center ICT
- **Netherlands eScience Center**
- **Oracle Spatial and Graph**, New England Development Centre (USA)
- **Rijkswaterstaat**
- **Fugro**
- **CWI, MonetDB**

Use case / test data set: AHN2

- NL surface
- 6 -10 pts/m^2 -> 640 billion pts
- 60,185 LAZ files, **987 GB**/11.64 TB
- (X, Y, Z) only

TU Delft Delft University of Technology

netherlands eScience center

ORACLE SPATIAL

monetdb

FUGRO

Rijkswaterstaat Ministerie van Infrastructuur en Milieu

Point Cloud Data Management Systems (PCDMS)

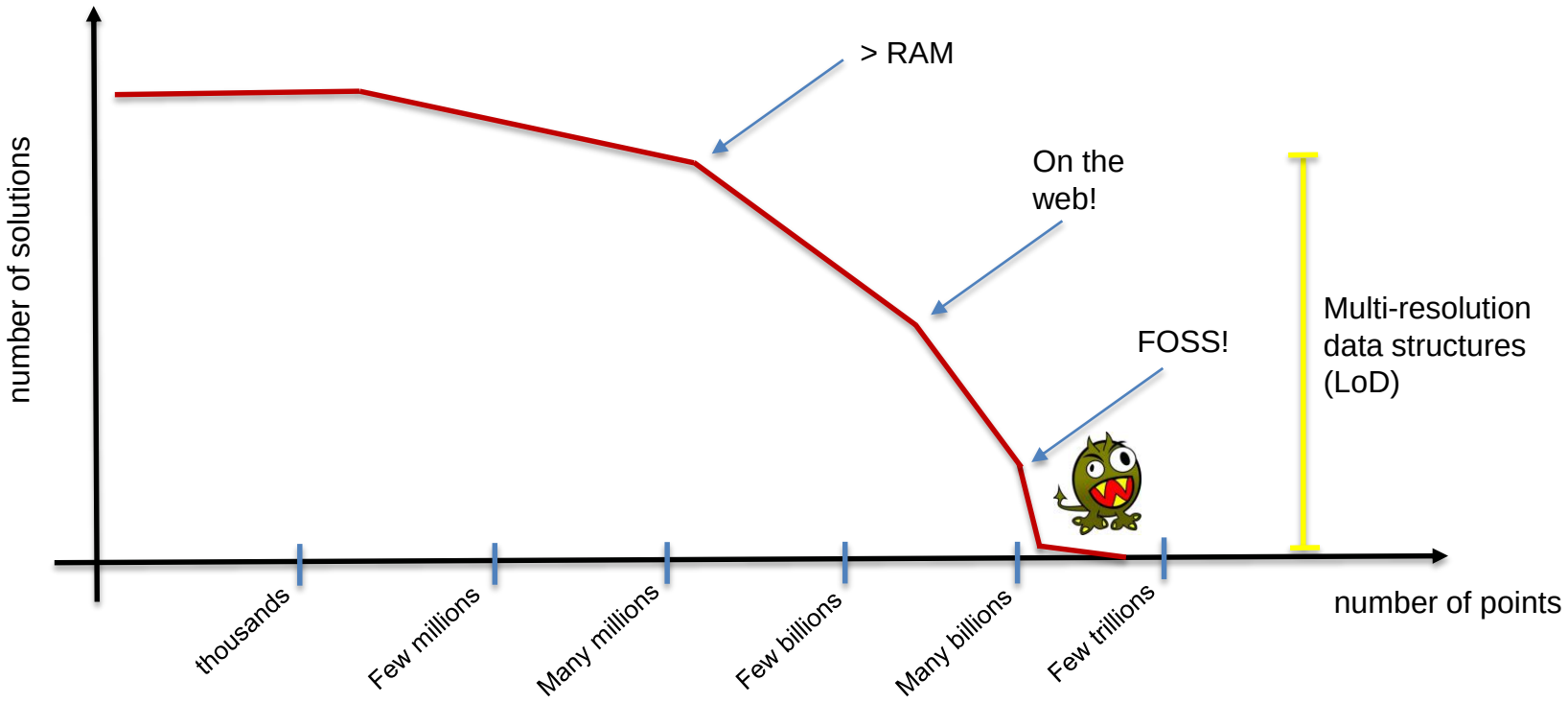
Storage model	Pro	Con
DB blocks PostgreSQL Oracle PDAL	• Storage (compression, lazperf) • Scaling • DB functionalities • Complex queries • PDAL queries (lazperf ~ LAStools/LAZ)	• Loading (make blocks) • Block overhead in queries (noticeable in simple queries) • Not native parallel • PDAL queries with many wasted points for large queries • PDAL not parallel
DB flat MonetDB Oracle PostgreSQL	• Faster loading • DB functionalities • Dynamic schema • Simple queries • Native parallelization (not PostgreSQL) • Promising SFC (scaling)	• Storage (except Exadata) • Not scaling (except Exadata, MonetDB, SFC) • Indexing (except Exadata)
File-based LAStools	• Storage (LAZ) • Data preparation • Best for simple queries (LAS)	• LAZ queries 1 order of magnitude slower • Limited functionalities • Fixed schema (LAS) • Scaling requires DB help • Not efficient parallel

More information:

- Peter van Oosterom et al. Massive point cloud data management: Design, implementation and execution of a point cloud benchmark. Computers and Graphics, 2015
- Oscar Martinez-Rubi et al. Benchmarking and improving point cloud data management in MonetDB. SIGSPATIAL Special 6, 11–18, 2015
- **Romulo Gonçalves et al. A new generation of Point Cloud Data Management Systems. Capturing Reality 2015 (M4) 2015/11/24 14:00**

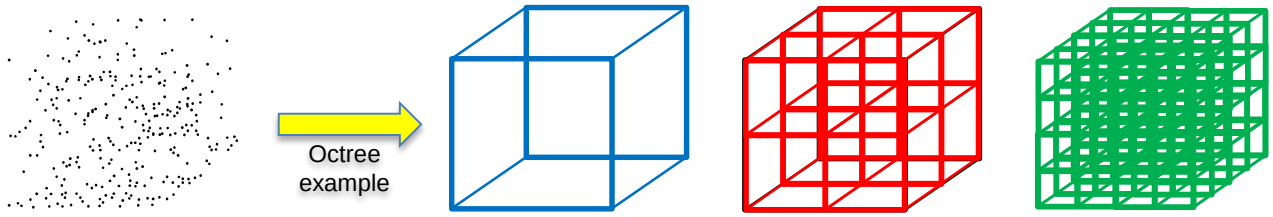
Point cloud visualization

- Existing **PCDMS's** aim at **analytic** purposes
- Existing **PCDMS's not** efficient **LoD** support
- **Visualization solutions**:



Point cloud visualization

- **Specific** data management solutions for **visualization**
  - **Large** point clouds → **Multi-resolution data structures** (quadtree, octree, kd-tree, etc.)



  - Many **desktop-based** solutions (and some really cool and efficient)
  - WebGL → **new point cloud web renderers (FOSS: Potree and Plasio)**
  - **Massive** point clouds → **Bottleneck**: expensive creation multi-resolution data structures

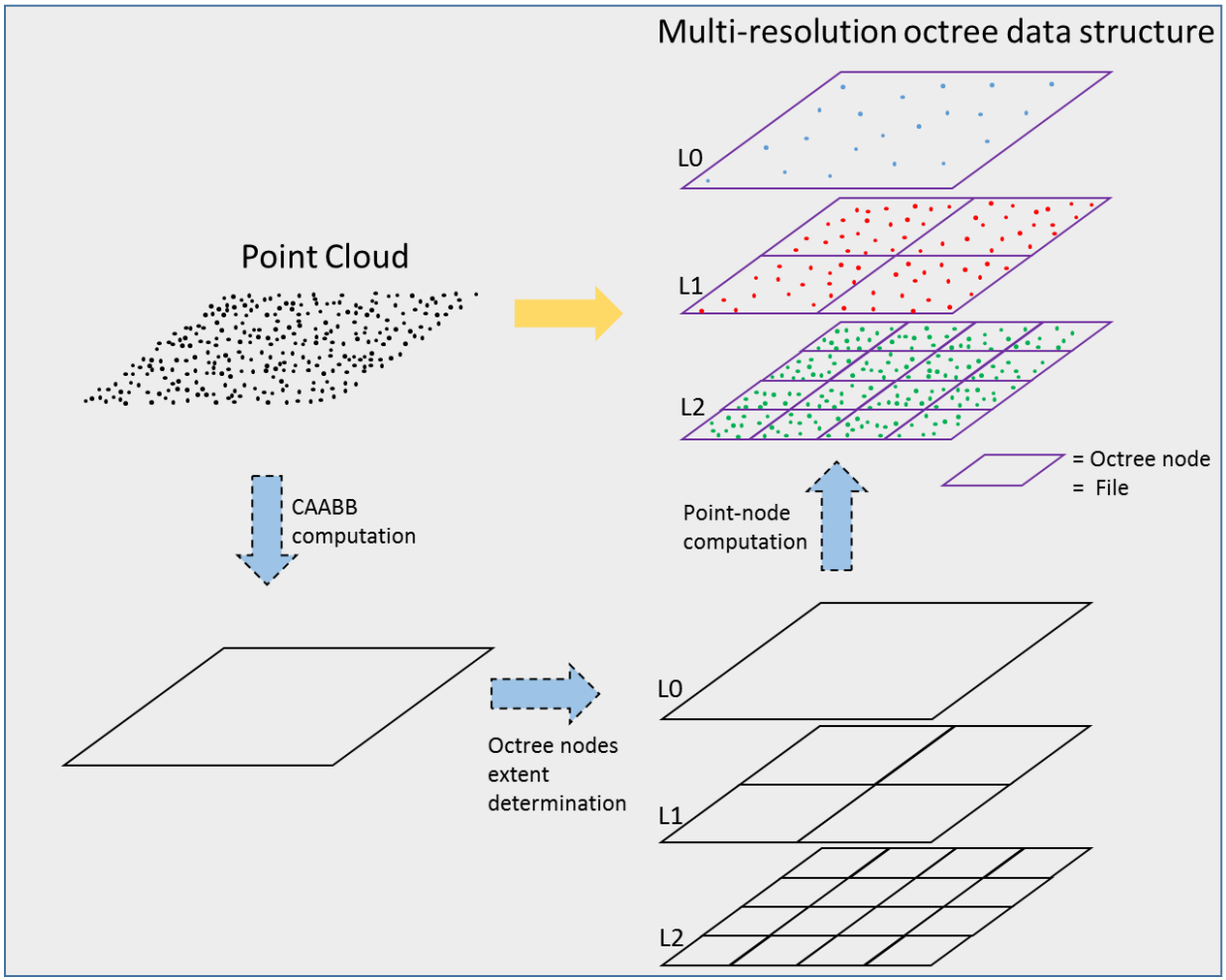
Potree

- Developed by **Markus Schütz**
- **Web renderer** for large point clouds (**WebGL** / three.js)
- **Modern web browsers** (no plugins required): Chrome, Firefox, Safari, Edge
- **Client-side** application (**server** “only” hosts **files)**
- Requires data re-organization: **PotreeConverter (LAZ, LAS or BINARY)**
- **Do not load full data**: Low-resolution data when far and gradually higher resolution data when closer
- **Color** on RGB, classification, elevation, etc.
- 4 **point rendering modes**: squares, circles, interpolation and splats
- 3 **point sizes modes**: fixed, attenuated and adaptive
- Eye-Dome-Lighting (**EDL**): illuminate point clouds without normal
- **Measurements** toolkit (distances, areas, height profiling)
- **FOSS**
- Based on **InstantPoints** (SCANOPY). Now under **Harvest4D**

TU WIEN TECHNISCHE UNIVERSITÄT WIEN

HARVEST 4D HARVESTING DYNAMIC 3D WORLDS FROM COMMODITY SENSOR CLOUDS

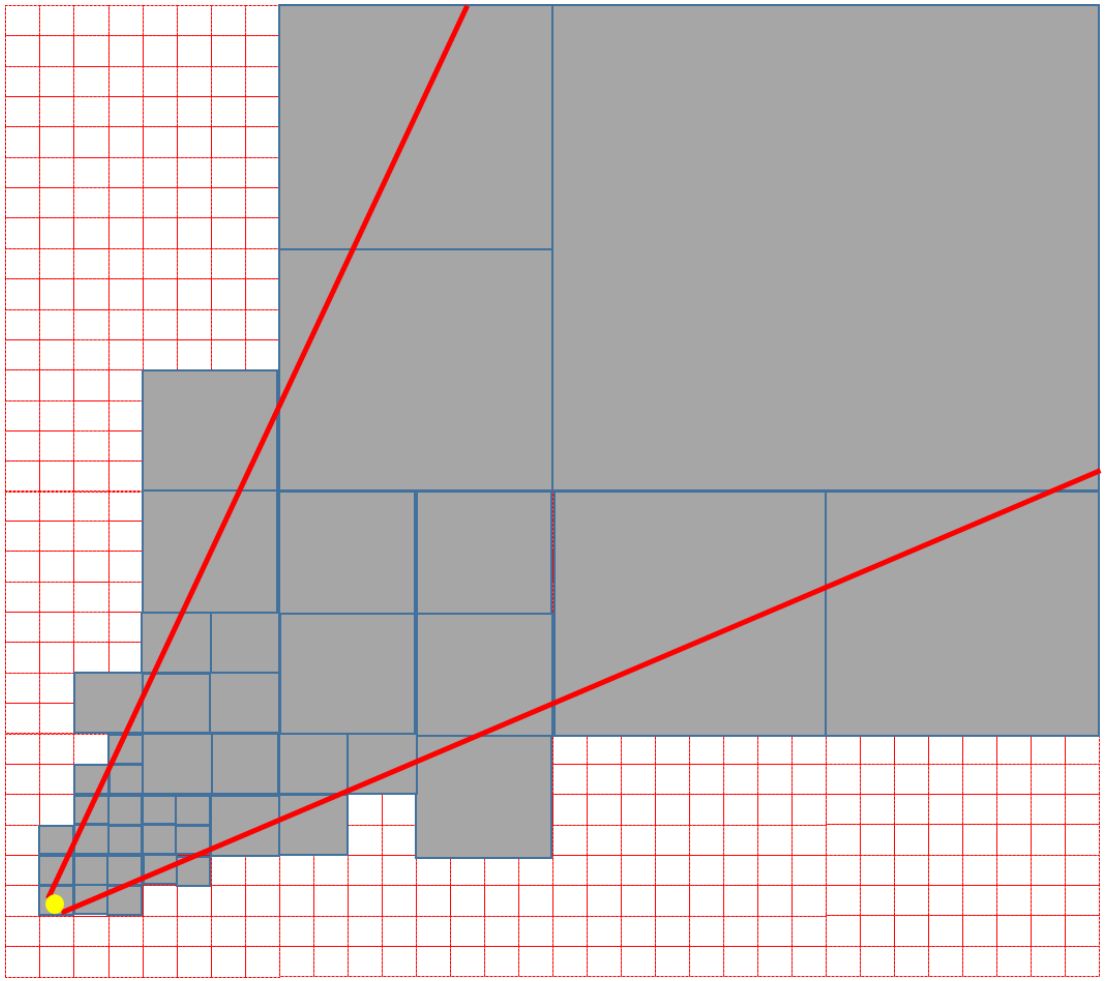
PotreeConverter (2D simplification)



User-configurable parameters:

- *spacing*: distance points root (L0)
- *levels*: number of levels
- *aabb*: Cubic axis-aligned bounding box

View frustum culling and level of detail calculations

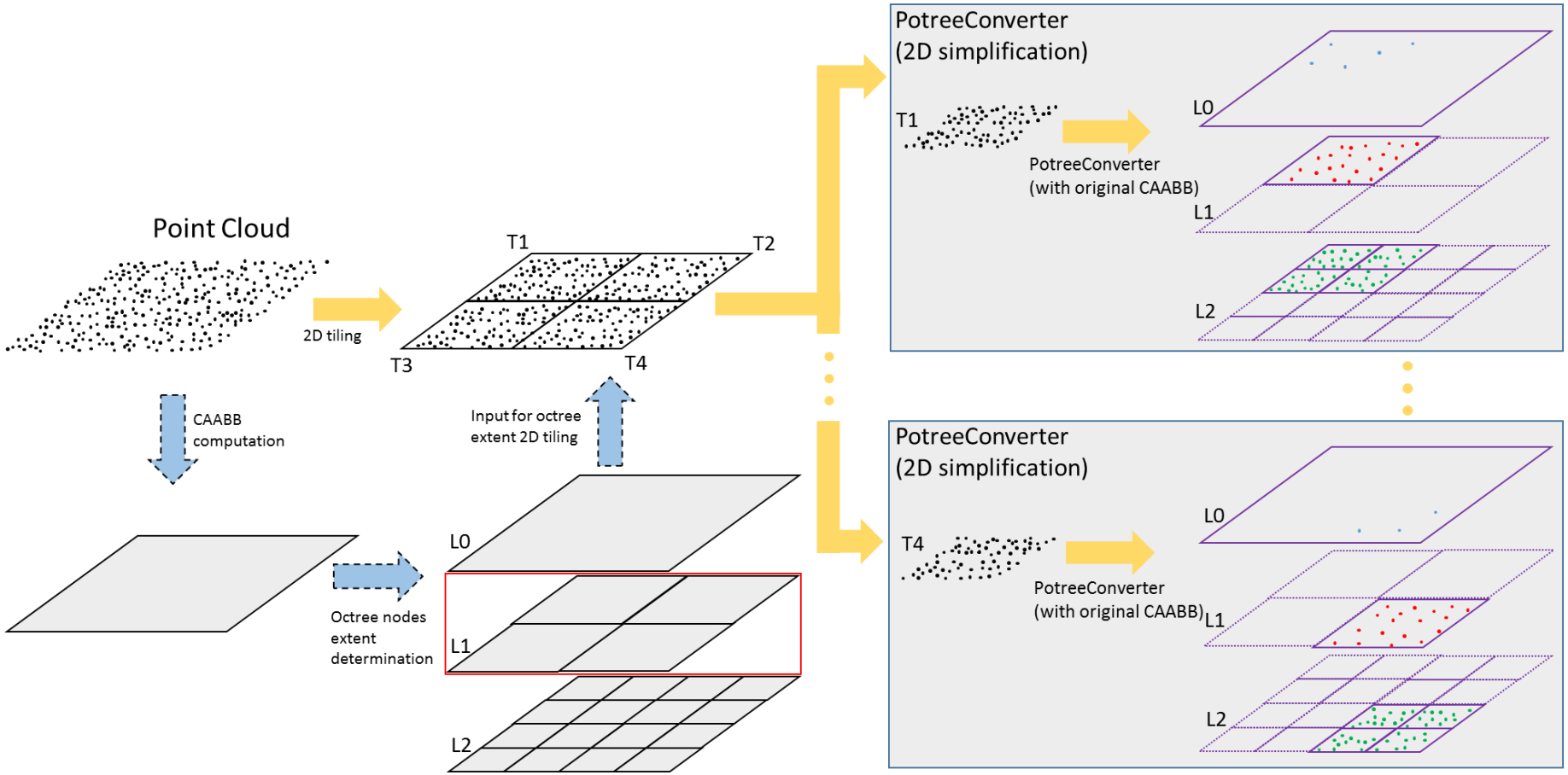


Massive point clouds

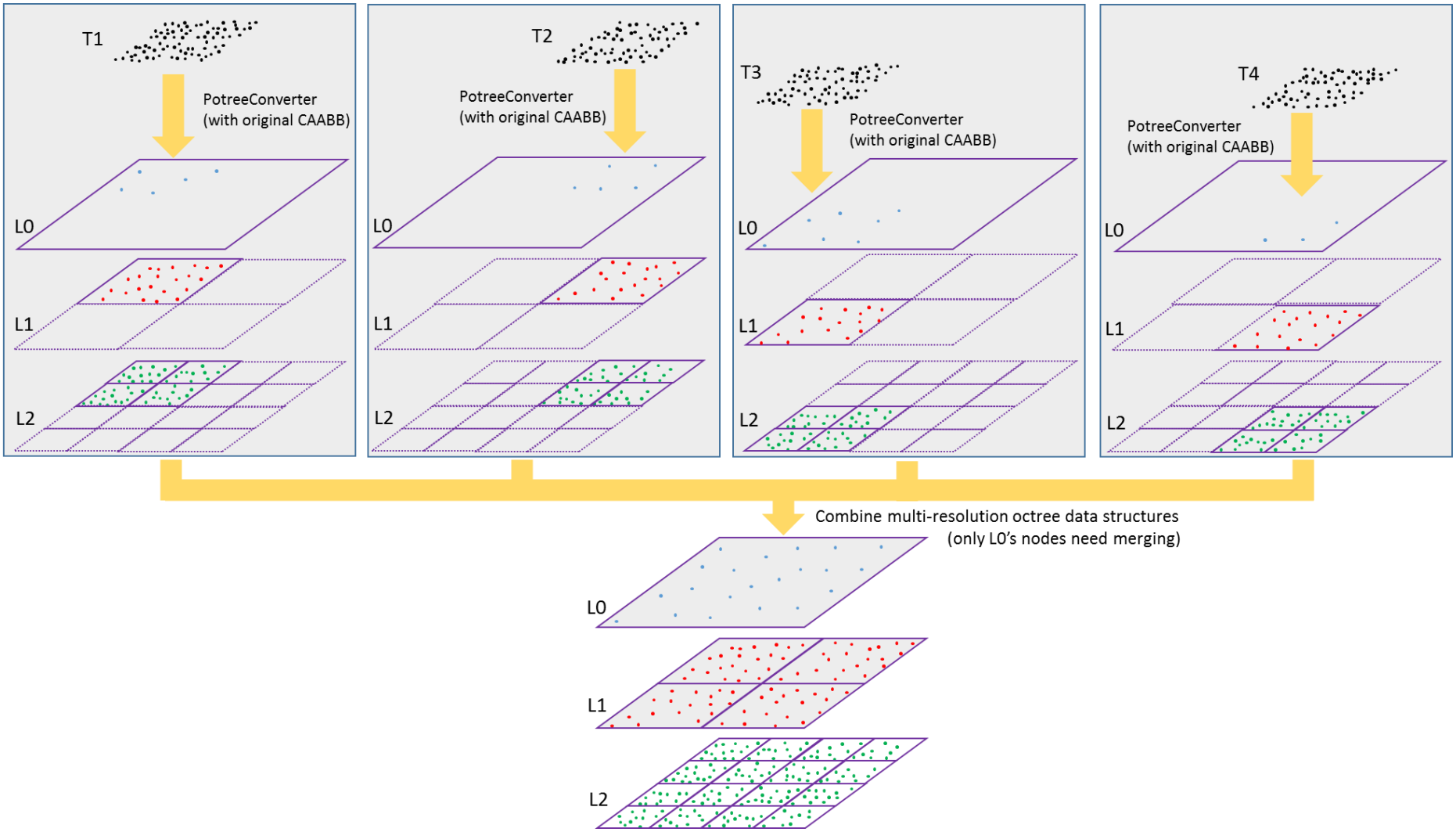
- **AHN2** use case (NL, **640 billion** points)
- PotreeConverter performance*: 250 million points / hour
  → **AHN2 estimate: 100 days**
- PotreeConverter is **single-process**
- **IO-bonded**
- Our solution: **Massive-PotreeConverter**
  - Divide and conquer approach
  - Exploits knowledge of spatial extents of octree nodes (also usable for other trees where nodes extent is independent of points)
  - Divides creation of massive octree into multiple independent tasks (creation of small octrees)
  - Tasks can run in multiple systems and cores
  - Small octrees are merged into massive octree
  - FOSS
  - https://github.com/NLeSC/Massive-PotreeConverter

*HP DL380p Gen8 server with 128 GB RAM and 2 x 8 Intel Xeon processors E5-2690 at 2.9 GHz, 2 x 41 TB SATA 7200 rpm in RAID 5 configuration

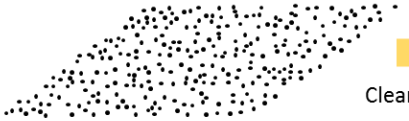
Massive-PotreeConverter (2D simpl.)



Massive-PotreeConverter (2D simpl.)

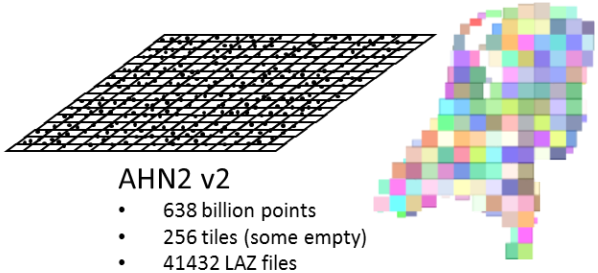


AHN2 conversion



Cleaning

2D tiling level 4 (PDAL)



AHN2 v0

- 640 billion points
- 60185 LAZ files
- "Dirty"
- Separated in objects and terrain
- 1 TB (529 GB terrain, 459 GB objects)

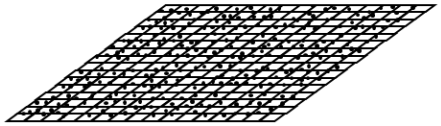
AHN2 v1

- 638 billion points
- 37588 LAZ files
- No errors / duplicates
- No objects/terrain separation
- 2.2 TB

AHN2 v2

- 638 billion points
- 256 tiles (some empty)
- 41432 LAZ files
- No errors / duplicates
- No objects/terrain separation
- 2.2 TB

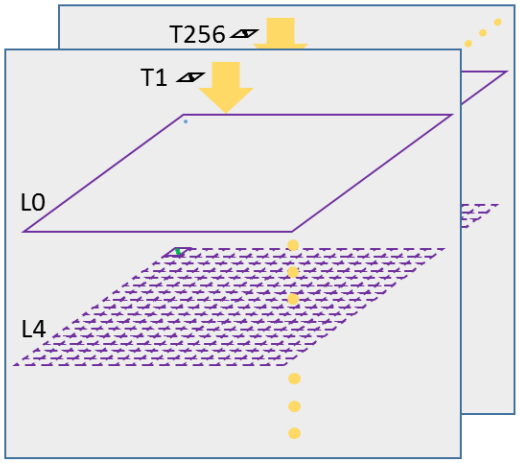
Sort/Index



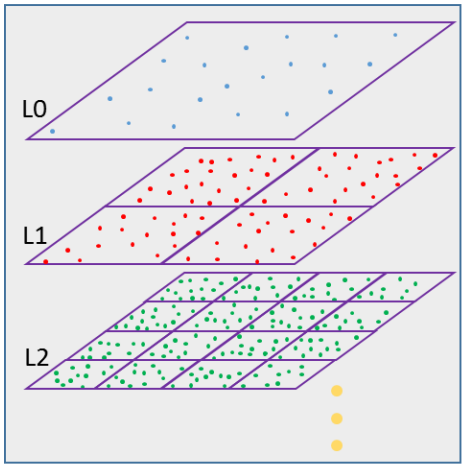
Distributed PotreeConverters

AHN2 v3

- 638 billion points
- 256 tiles (some empty)
- Sorted/Indexed (LAStools)
- 41432 LAZ files
- 41432 LAX files
- No errors / duplicates
- No objects/terrain separation
- 1.6 TB



Merging process



AHN2 v4

- 597 billion points
- 256 octrees (some empty)
- 14 levels per octree
- 38285863 LAZ files
- No errors / duplicates
- No objects/terrain separation
- 1.6 TB

AHN2 v5

- 597 billion points
- 1 octree
- 14 levels
- 38233895 LAZ files
- No errors / duplicates
- No objects/terrain separation
- 1.6 TB

AHN2 conversion

level	#files	files_fact	#points	points_fact
0	1		34,045	
1	4	4,00	134,786	3,96
2	14	3,50	541,973	4,02
3	41	2,93	2,205,484	4,07
4	143	3,49	8,833,283	4,01
5	499	3,49	36,081,908	4,08
6	1,804	3,62	155,411,383	4,31
7	6,767	3,75	668,597,511	4,30
8	25,939	3,83	2,834,989,373	4,24
9	101,057	3,90	11,355,433,955	4,01
10	398,423	3,94	39,911,483,676	3,51
11	1,584,598	3,98	112,993,998,398	2,83
12	6,671,815	4,21	259,014,500,658	2,29
13	29,442,790	4,41	170,207,571,211	0,66
Total	38,233,895		597,189,817,644	

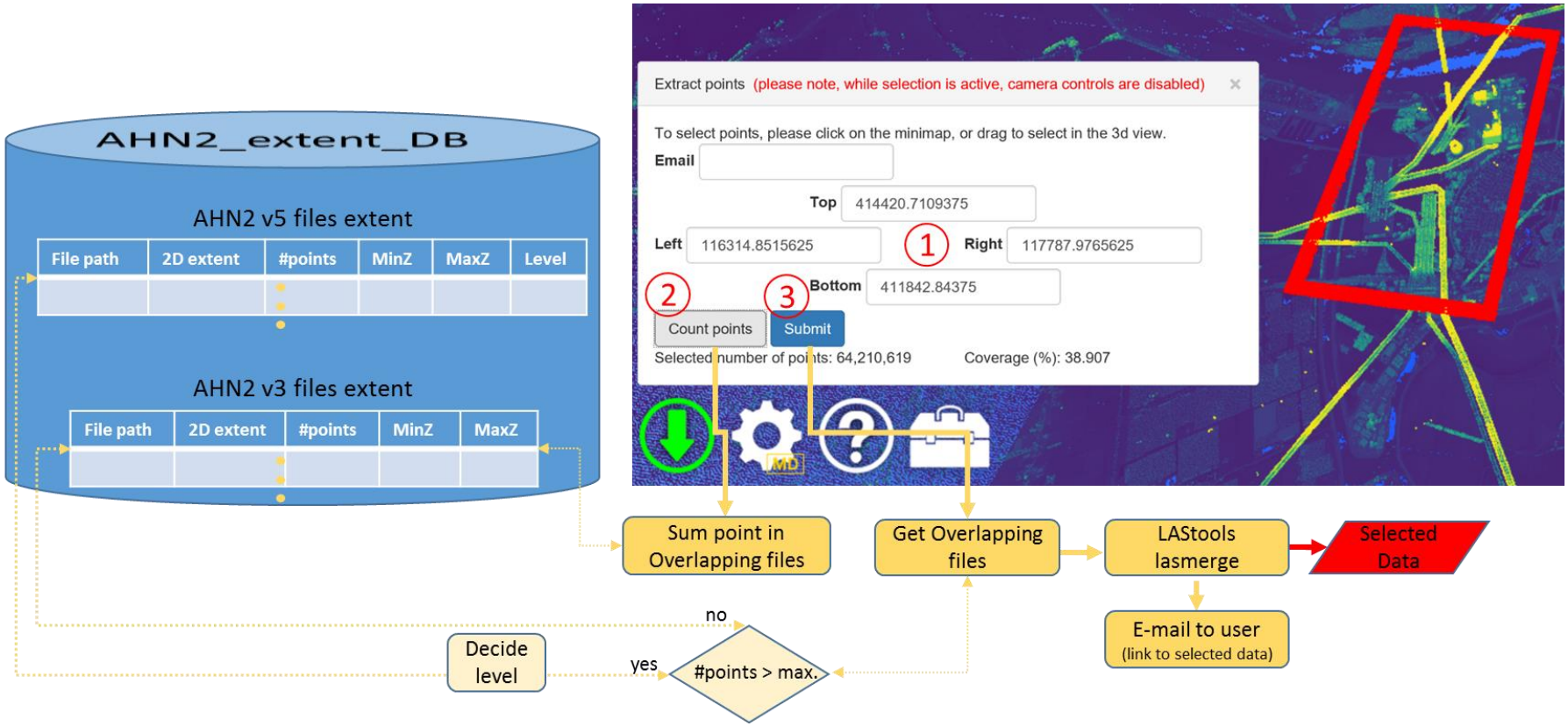
AHN2 web viewer and download tool

http://ahn2.pointclouds.nl

AHN2 web viewer and download tool

- **4 quality options: low, standard, high and ultra**
- 2 navigation modes: GoogleEarth-like and keyboard interaction
- Geographic name **search bar** (Bing Geocoding service converts names to coordinates)
- 2D orientation **minimap** (3D field-of-view depiction)
- **Height coloring** configuration
- **Demo mode** (download/upload demo paths)
- **Speed control**
- **Potree features**: Measurement toolkit, color by other attributes, etc.
- **Multi-resolution download tool**

Multi-resolution download tool



Conclusions and future work

- **D&C algorithm** for creating massive multi-resolution data structures suitable for visualization
- **FOSS** implementation for Potree/PotreeConverter (octree)
  → **Massive-PotreeConverter**
- Used for **AHN2** → public web service (**http://ahn2.pointclouds.nl**)
- **Proof-of-Principle** massive point clouds can be web-visualized with FOSS
- Future work:
  - Add **time** (AHN2-AHN3)
  - Mix with **imagery** tiles to get color (beta)
  - Trees with **all points** (current PotreeConverter drops too-close points → **SOLVED!**)
  - Handle **millions** octree nodes/**files** (key-value stores, HTTP Range Retrieval Requests, etc.)
  - ***OpenPointCloudMap***: More countries → all planet, flexible to add/update point clouds
  - *Synchronize efforts with **standardization** ones (OGC-PC-DWG),OSGEO PointDown*
  - *Integration Potree/MassivePotreeConverter with PDAL/Plasio/Entwine/Greyhound*
  - ***nD-PointCloud** (submitted H2020 FET Open): http://nd-pc.org*

Thank you for your attention