Massive Geometric Algebra

Requirements and Applications for dealing with Big Data

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AHM Software GmbH / Louisiana State University

Background: Cutting-Edge Astrophysics

- Application: *Numerical Relativity*
  - Simulation of General Relativity via numerical means in the computer

→ Computationally intensive

→ Requires high performance computing (HPC)

→ Requires handling big data

→ Requires support of generic mathematical concepts

→ Differential geometry, Riemannian Geometry, Curved Space, Tensor Algebra

Max-Planck Institute for Gravitational Physics (Albert-Einstein Institute), Potsdam, Germany
National Center for Supercomputing Applications (NCSA), Champaign, Illinois, USA

Gravitational Waves

US National Science Foundation
LIGO International Consortium

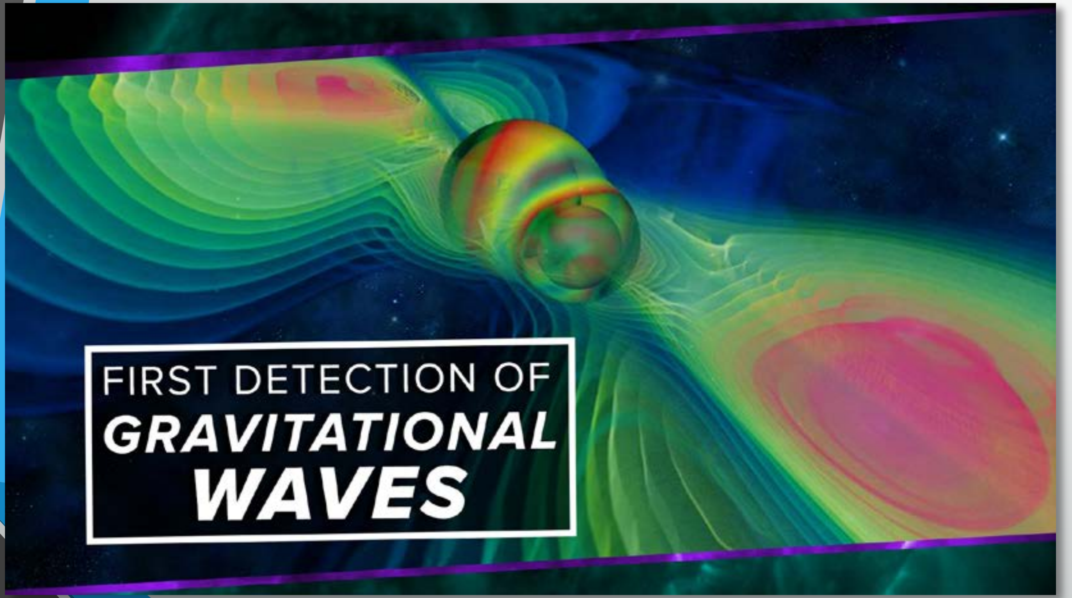

catchnews

SPORTS | POLITICS | BUSINESS | INTERNATIONAL | CULTURE | HEALTH | SCIENCE & TECH

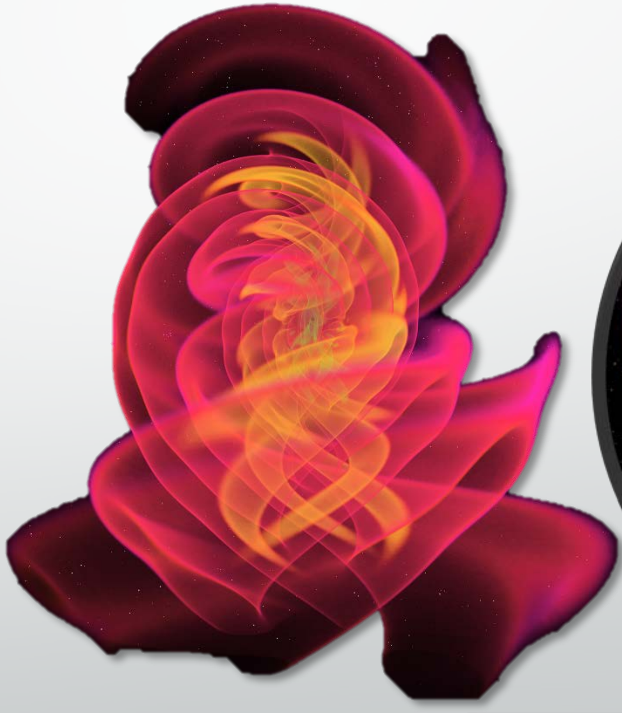
LIGO detects gravitational waves for the second time

SPEED NEWS DESK | First published: 16 June 2016, 11:26 IST

16. Feb 2015



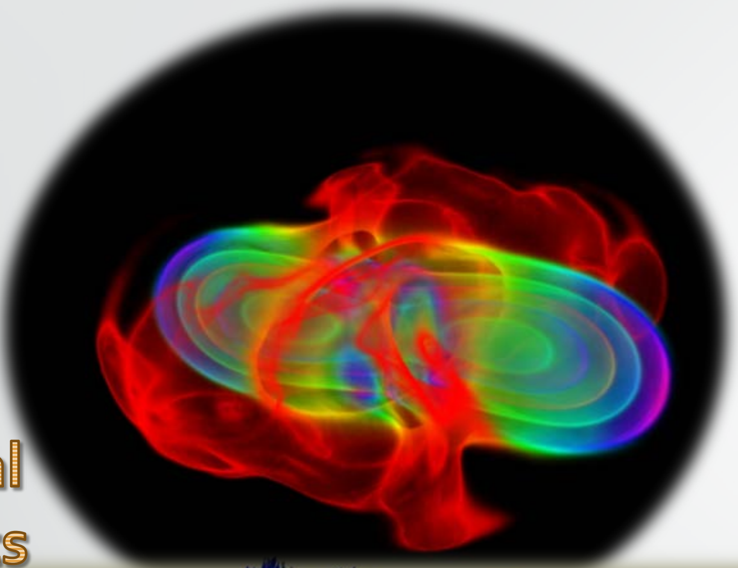
12GB raw data, 1999

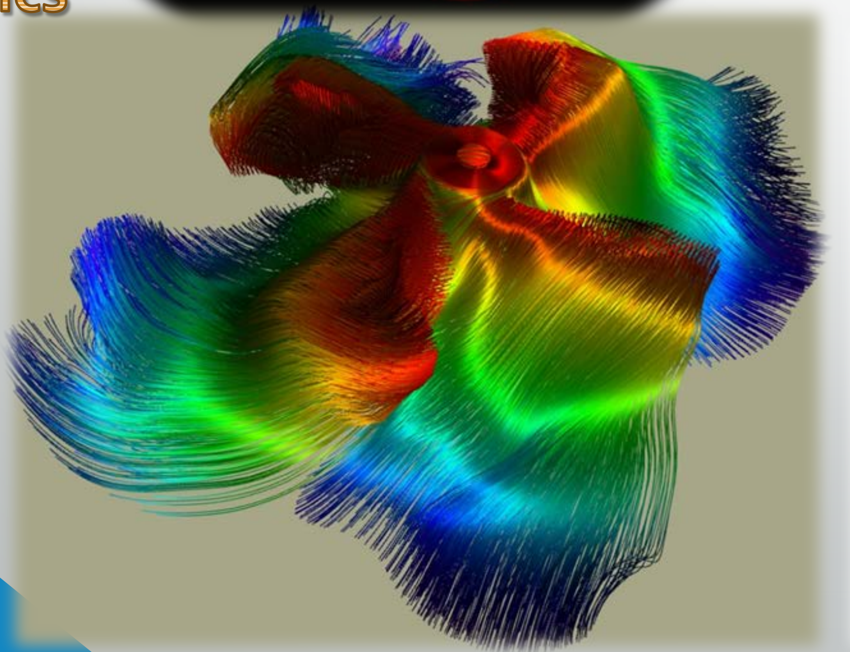


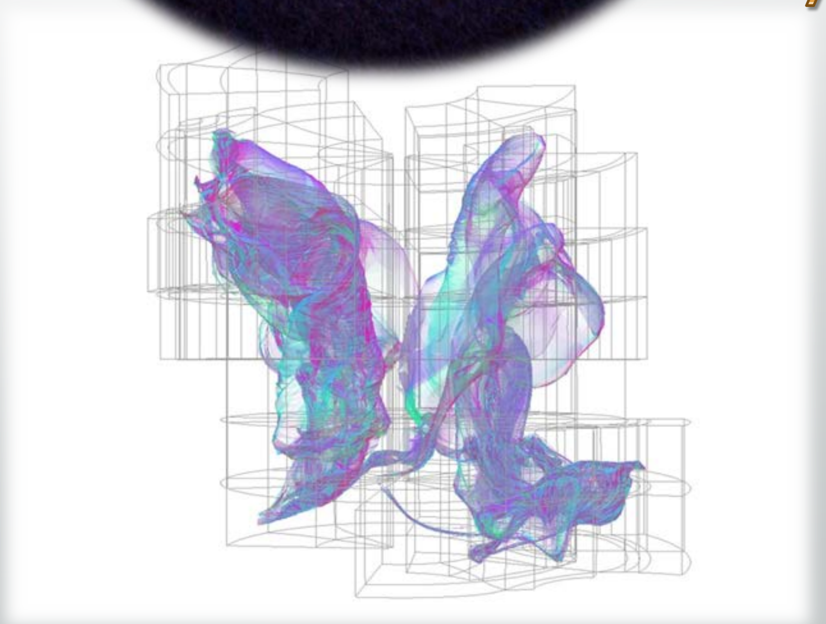
450GB raw data, 2016

Background: Big Data in Big Flavors in HPC

Computational
Fluid Dynamics

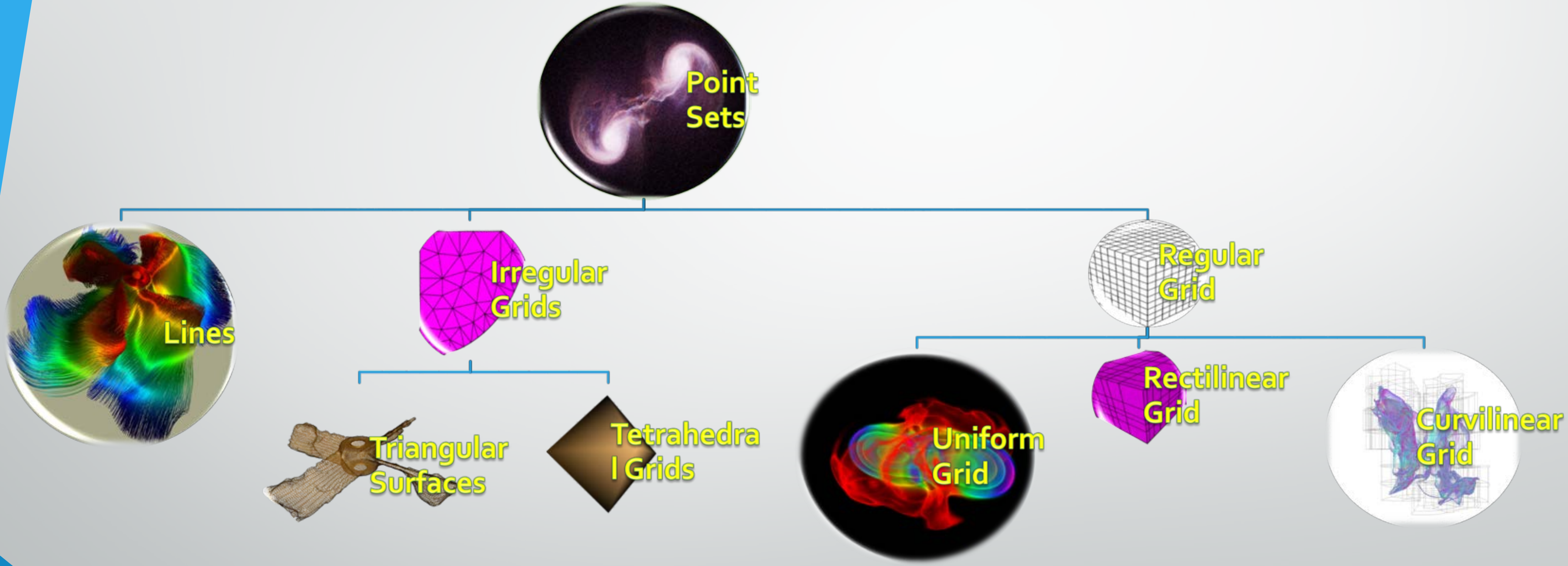




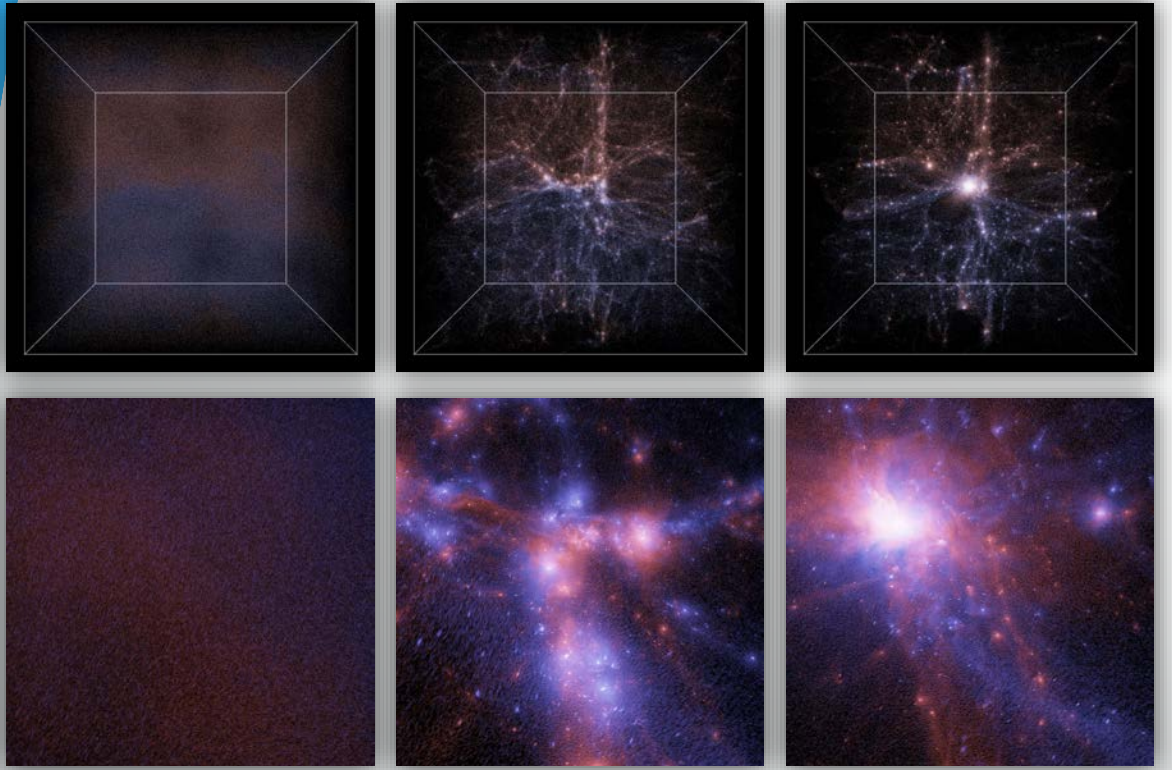


Particle
Systems

Background: Points as Common Base



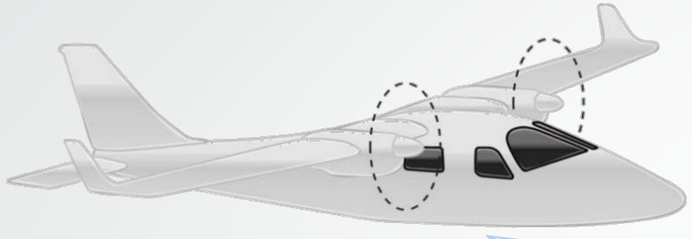
Application: Evolving Galaxies



2011, University of Innsbruck, Austria

- 16 Million particles, each representing one dust/darkmatter/newly formed stars
- Cosmological evolution over several billion years
- 280GB of binary data
- Velocity given for each particle

Background: What does AHM do?



GREENSURVEY

AIRBORNE HYDROMAPPING

- Software HYDROVISH -

LIDAR, which stands for *Light Detection and Ranging*, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

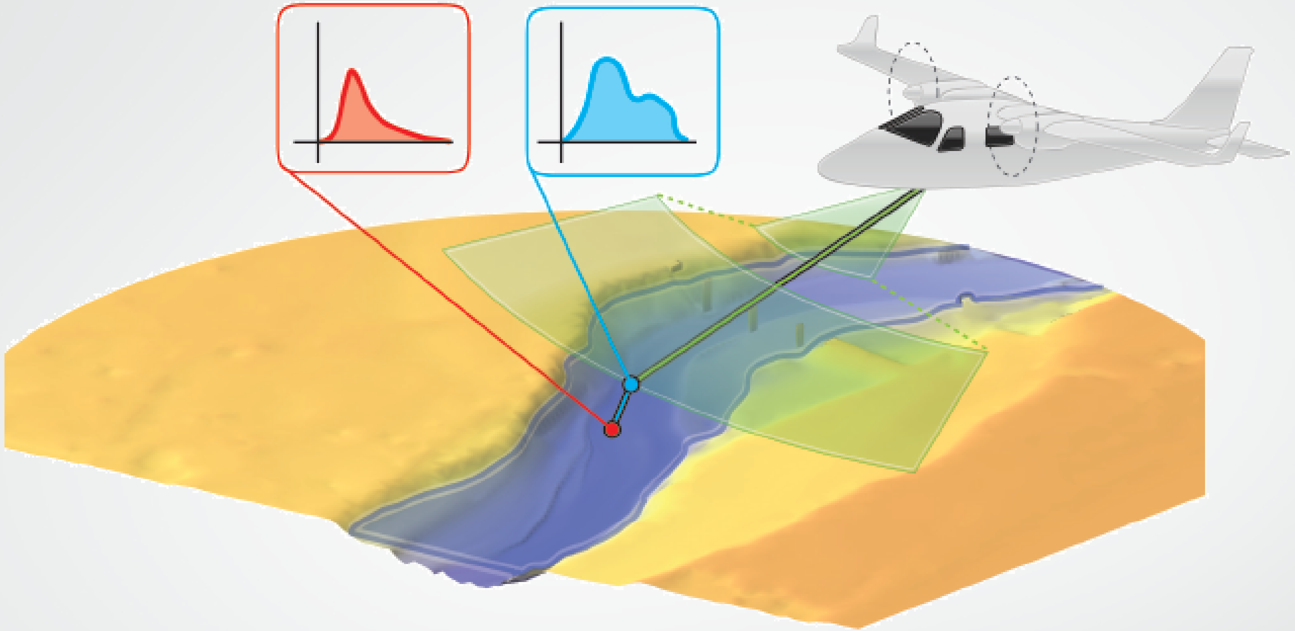
AIRBORNE HYDRO MAPPING

AIRBORNE LAND MAPPING

AIRBORNE NATURE MAPPING

AIRBORNE ICE&SNOW MAPPING

Airborne HydroMapping



What is Hydro Mapping?

Airborne Hydromapping is a new technology for the very detailed survey of rivers, lakes and reservoirs. This airborne-operated, ***water-penetrating laser system*** is considered as a technical revolution for the comprehensive and simultaneous monitoring of shallow water bodies (**depths down to 8 m**), and the adjacent foreland with an **accuracy of less than 10 cm**.

The hydromapping concept and HydroVISH

Fixed wing and helicopter survey platform concepts

- Lightweight scanner
- Compact layout
- Low energy consuming
- Easy installation handling

GREENSURVEY

GREENSURVEY

AHM AIRBORNE HYDRO MAPPING

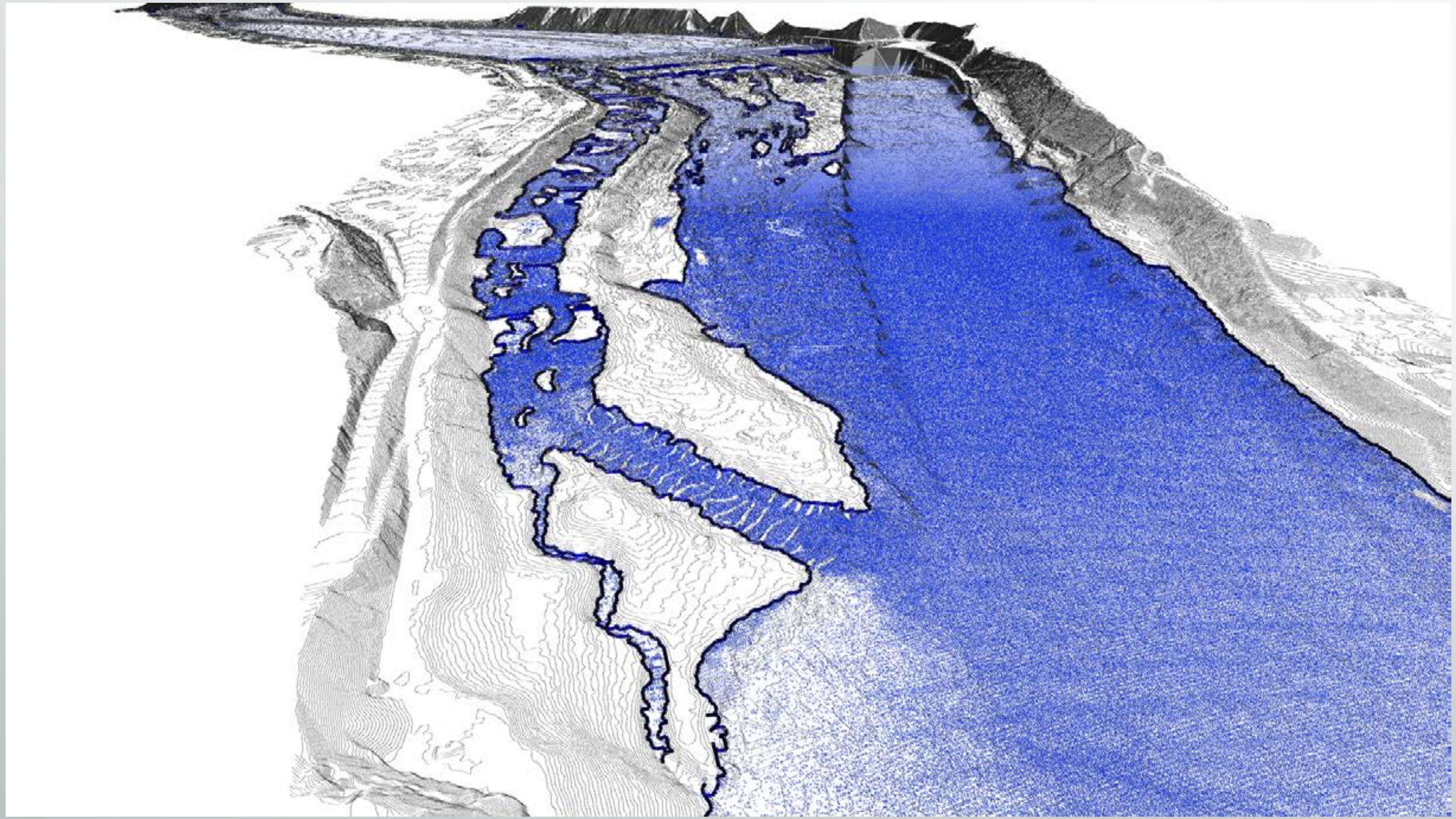
AHM AIRBORNE LAND MAPPING

AHM AIRBORNE NATURE MAPPING

AHM AIRBORNE ICE&SNOW MAPPING

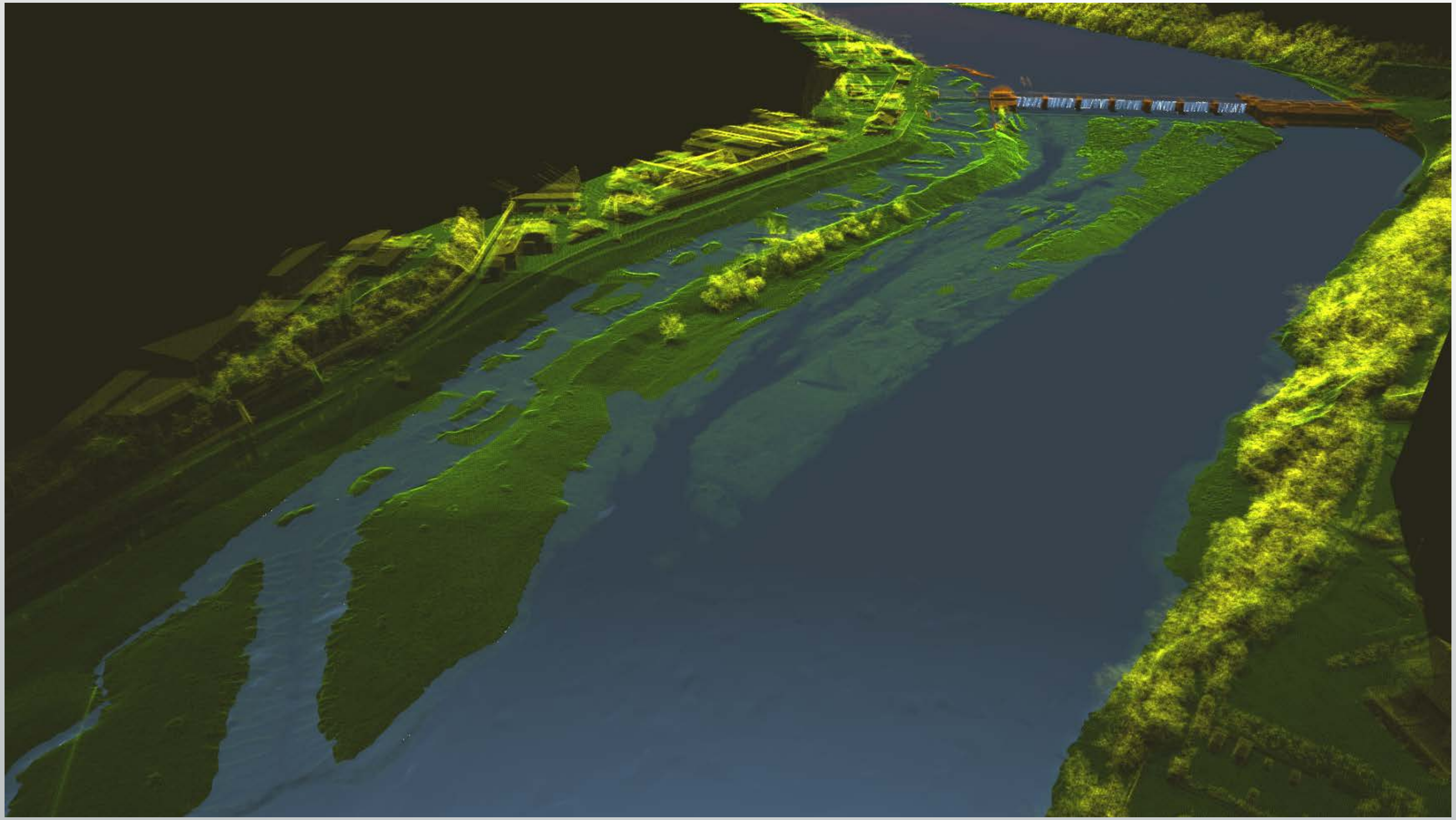
Bathymetric survey projects Rheinfelden

Bathymetric survey projects Rheinfelden

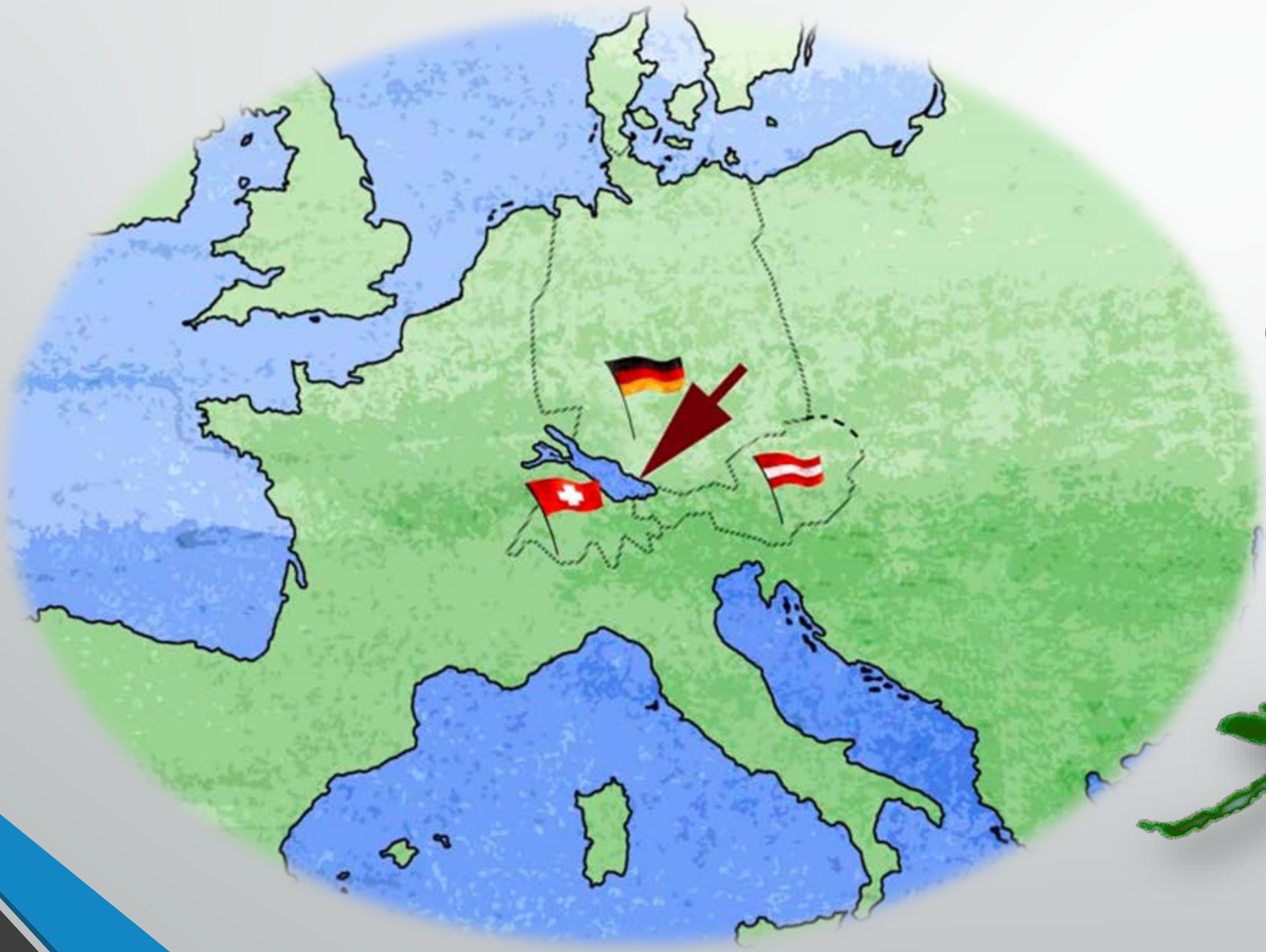


Bathymetric survey projects Rheinfelden

Shading of the water surface:



Application: Lake Constance, 2015



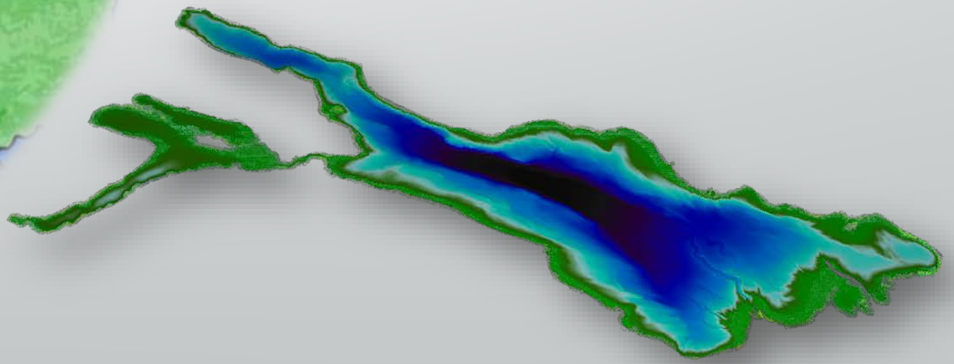
Europe‘s 3rd Largest Lake
Bordering Austria, Germany, Switzerland

11,500 km^2

63km (max) x 14 km (max) –

LIDAR resolution at 80 points / m²

→ 600GB binary raw data



Project: Lake Constance, 2015

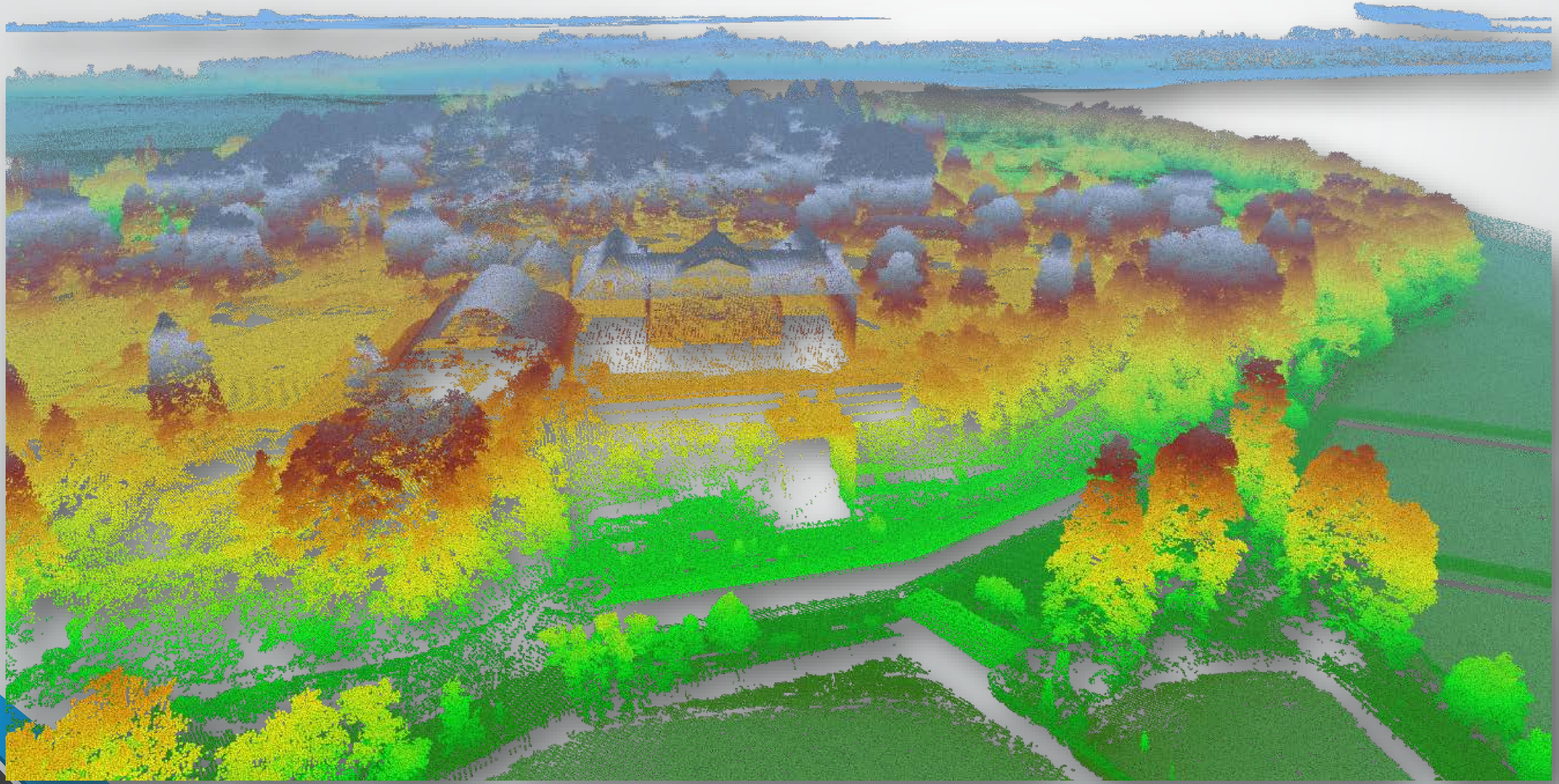
Large Lake at border of Austria, Germany, Switzerland
11,500 km^2
63km (max) x 14 km (max) –

LIDAR resolution at 80 points / m^2

→ 600GB binary raw data

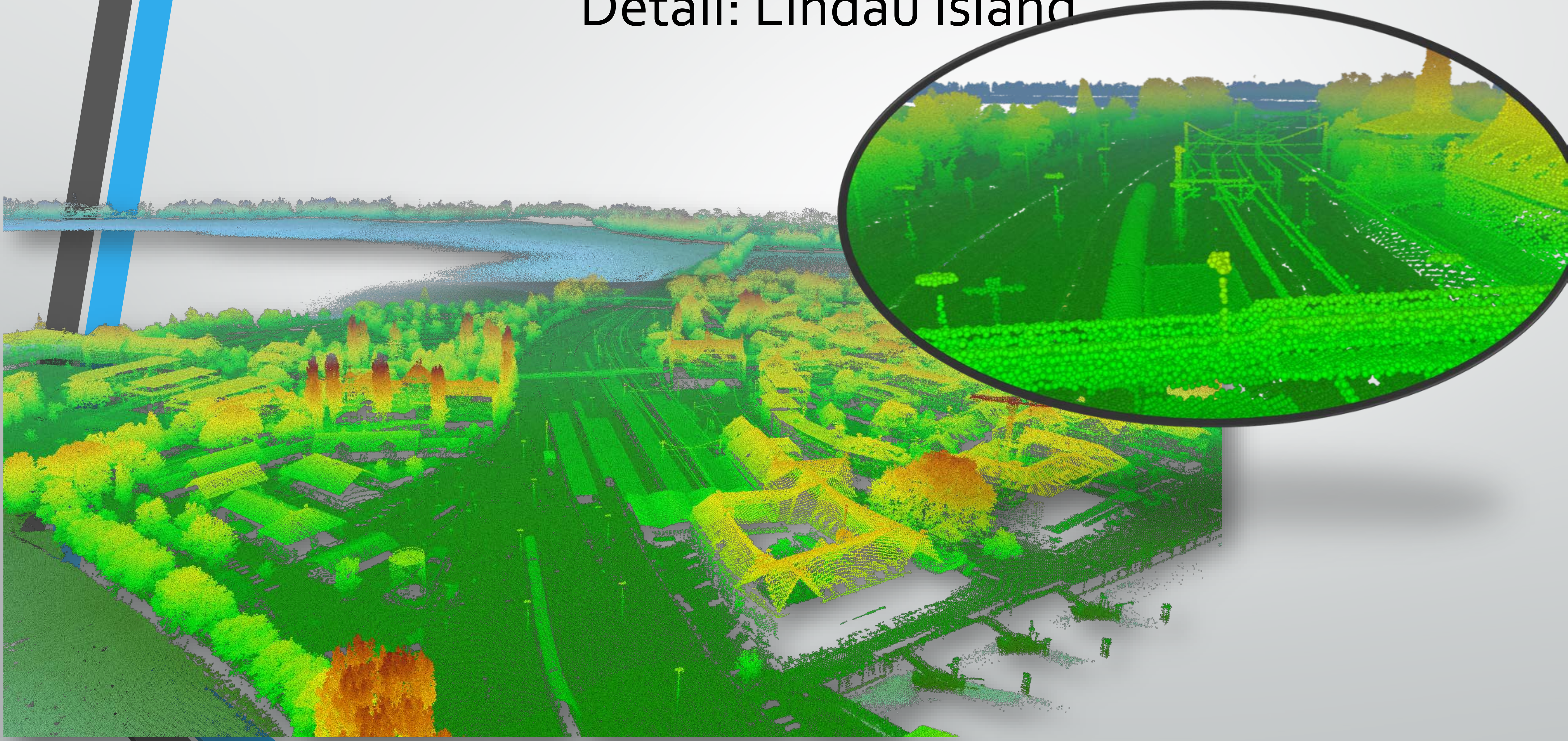
Detail: Mainau Island

80 points / m^2

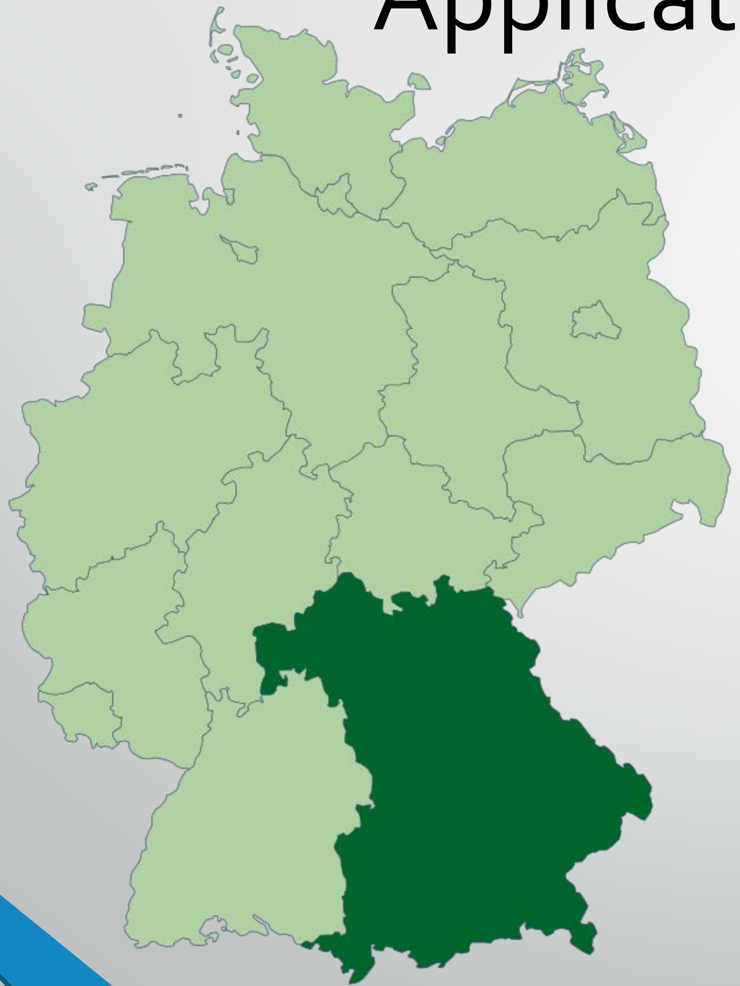


Detail: Lindau Island

Detail: Lindau Island



Application: Bavaria, 2016 – 4TB



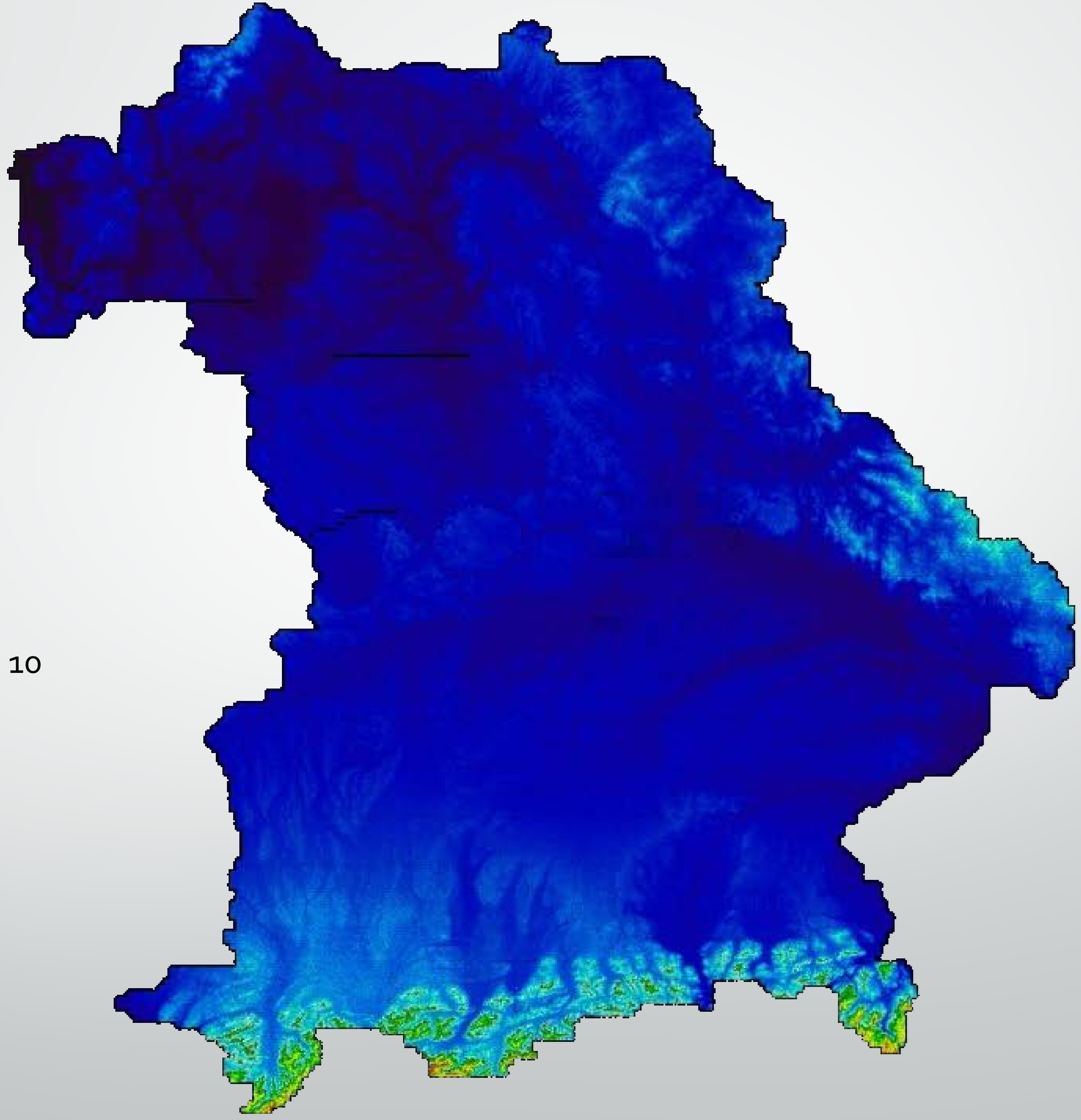
- Largest State of Germany, 70,549.44 km^2
- Data resolution: $1m^2$
- > 73000 files of 1 km^2

- Faces limitations in OS: Windows max 2048 files openable at the same time
- Faces limitations in hard disk space
- Work in progress

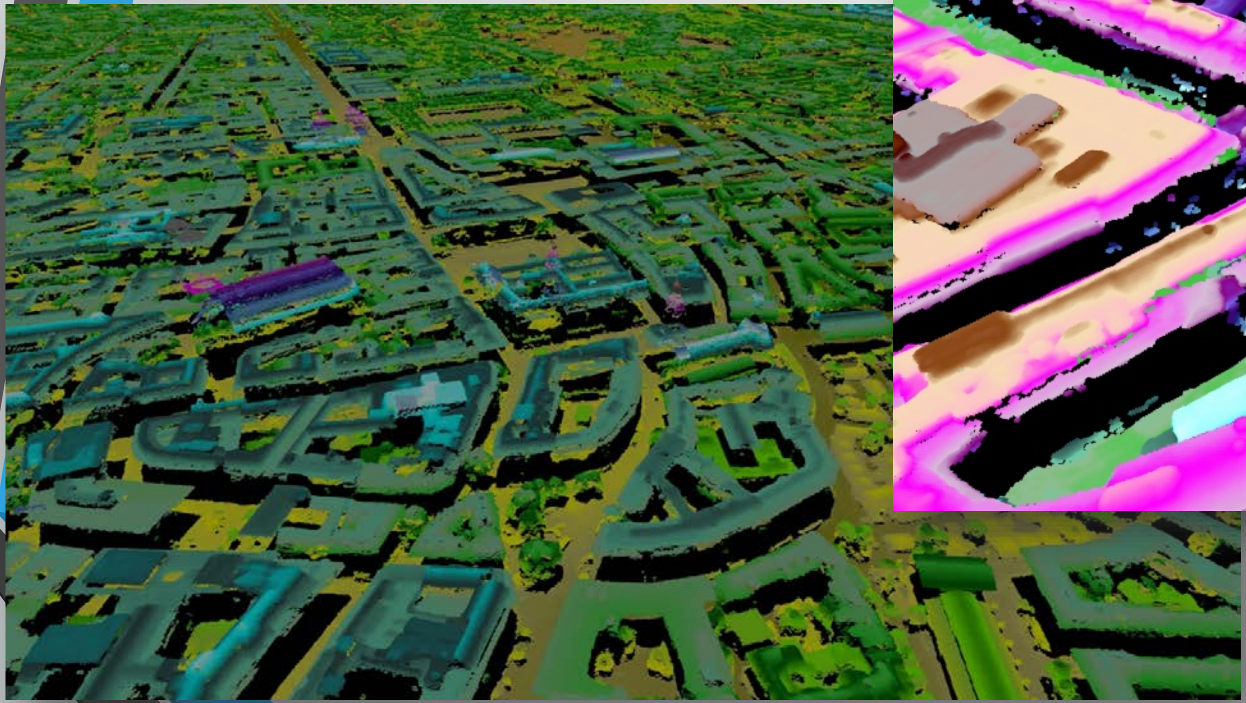
Bavaria, First Results

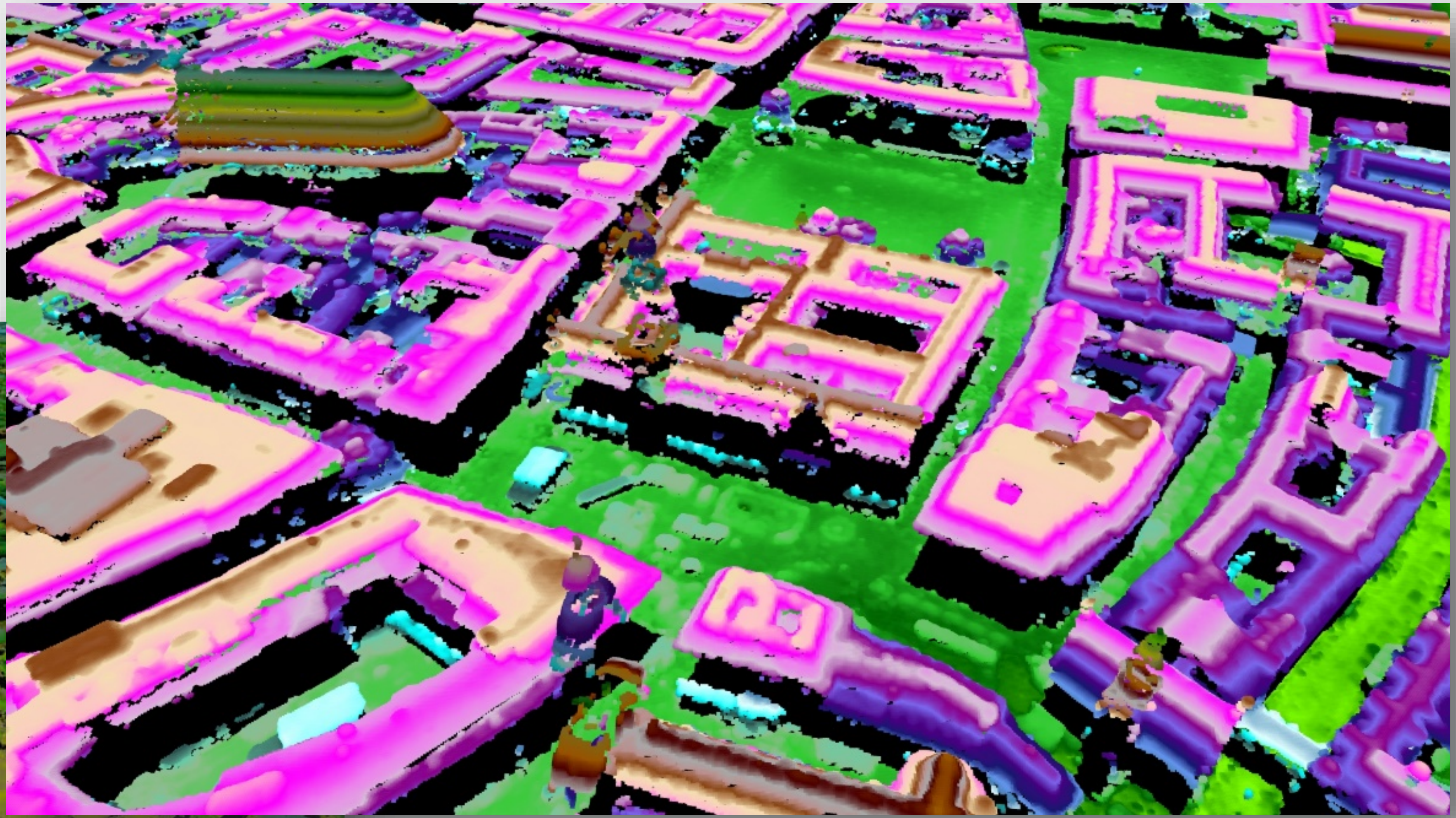
2TB Finest Resolution at 1m

2TB Hierarchical representation in 10 levels, Refinement factor 4



Bayern Detail (Munich, City Hall)

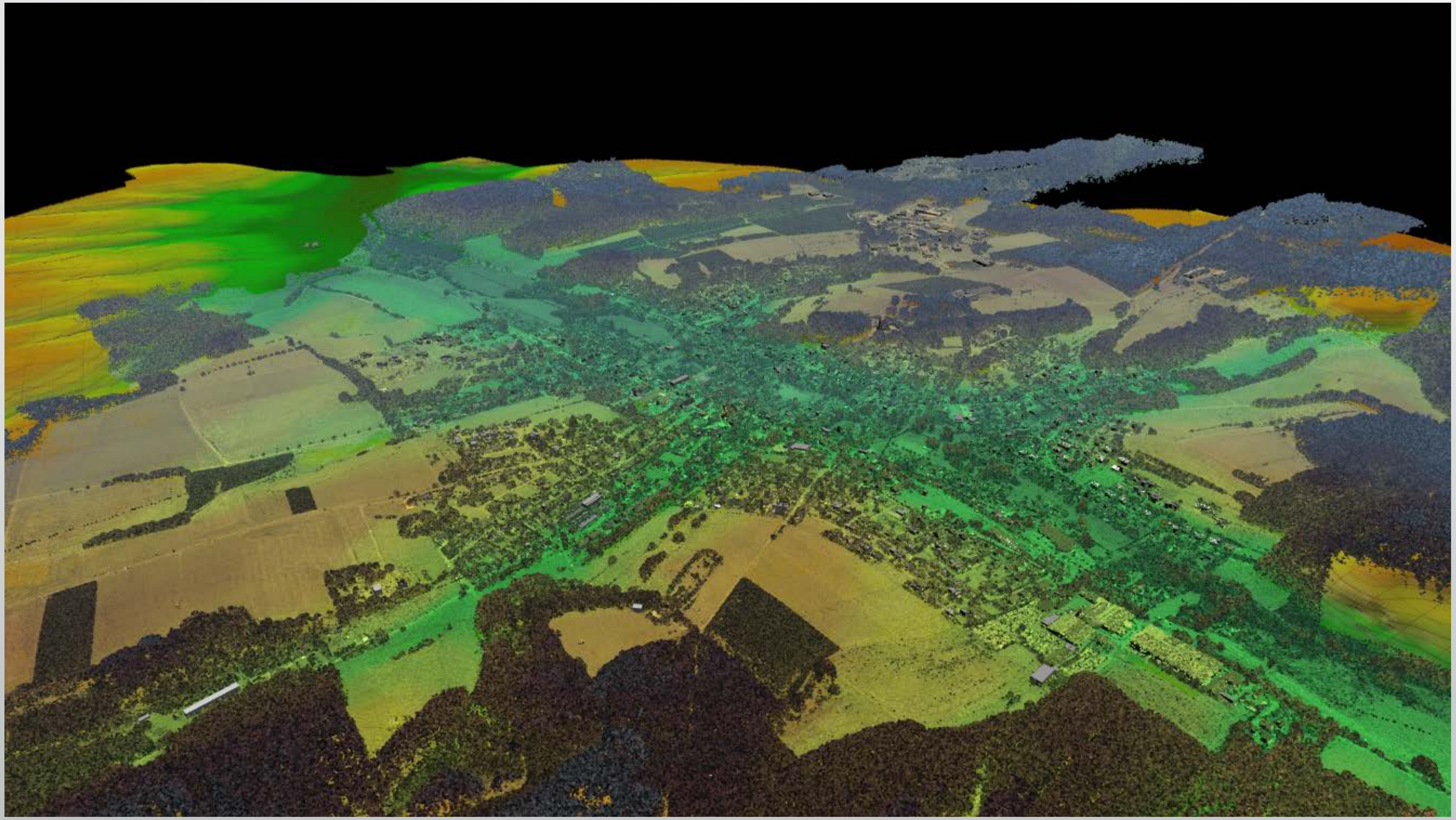




LIDAR Point Clouds & GIS data

Visualizing and Analysing massive point clouds

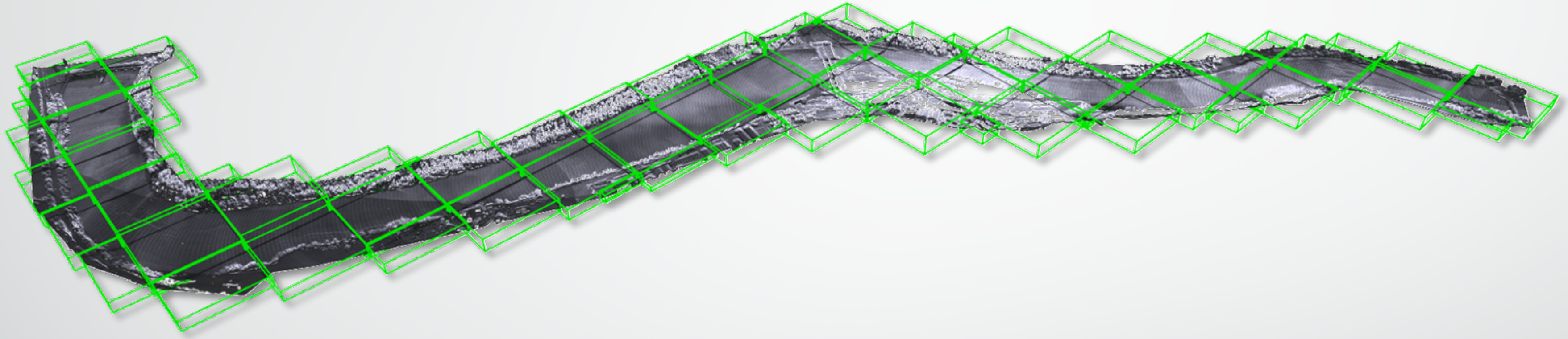
Massive Point Clouds – 10GB, 100GB, 10TB… (LIDAR observations)

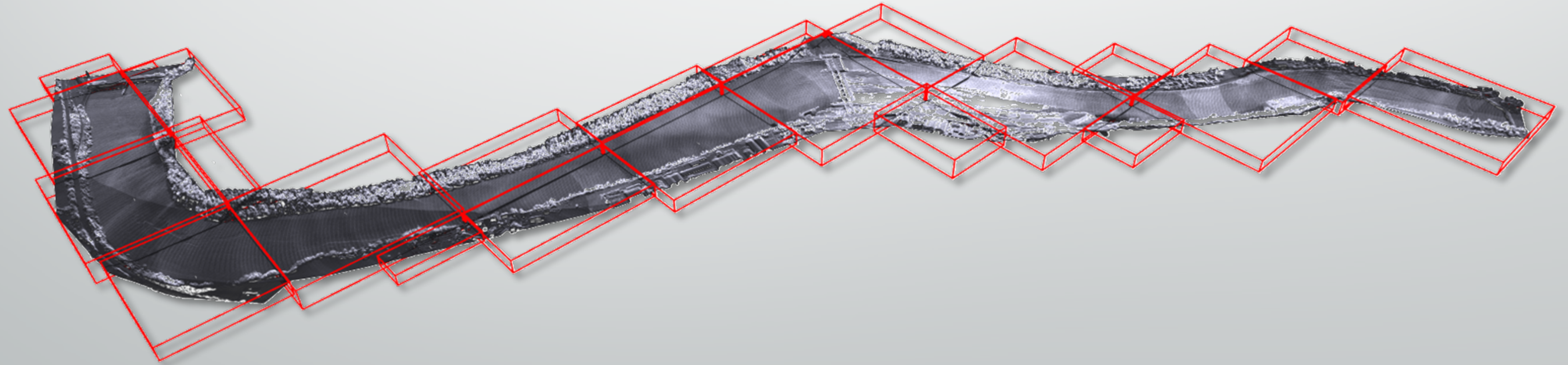


Objects are known via Point Coordinates

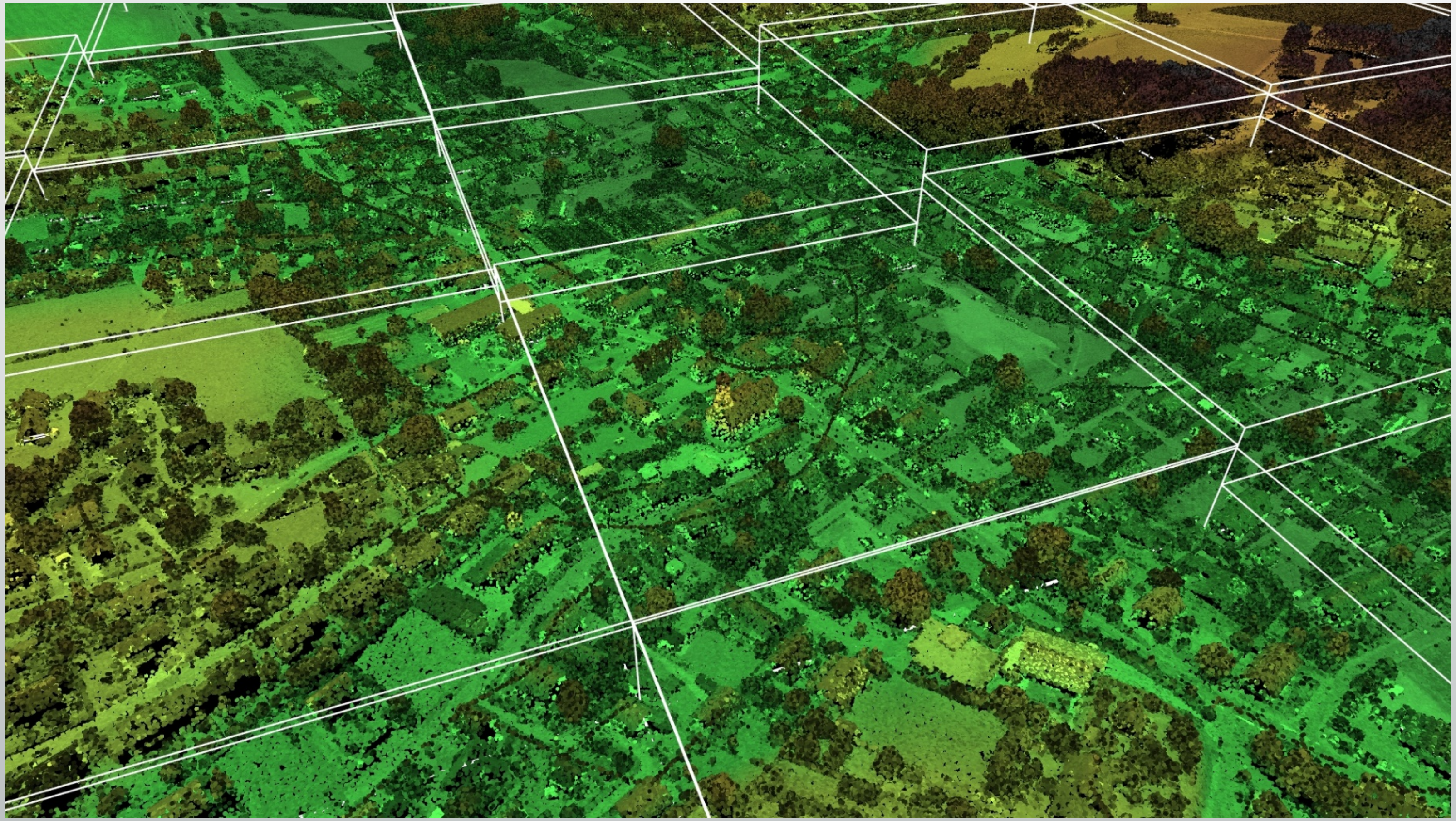
Data Handling #1: Fragmentation

Arbitrary fragment sizes to optimize performance (no requirement to be uniform):





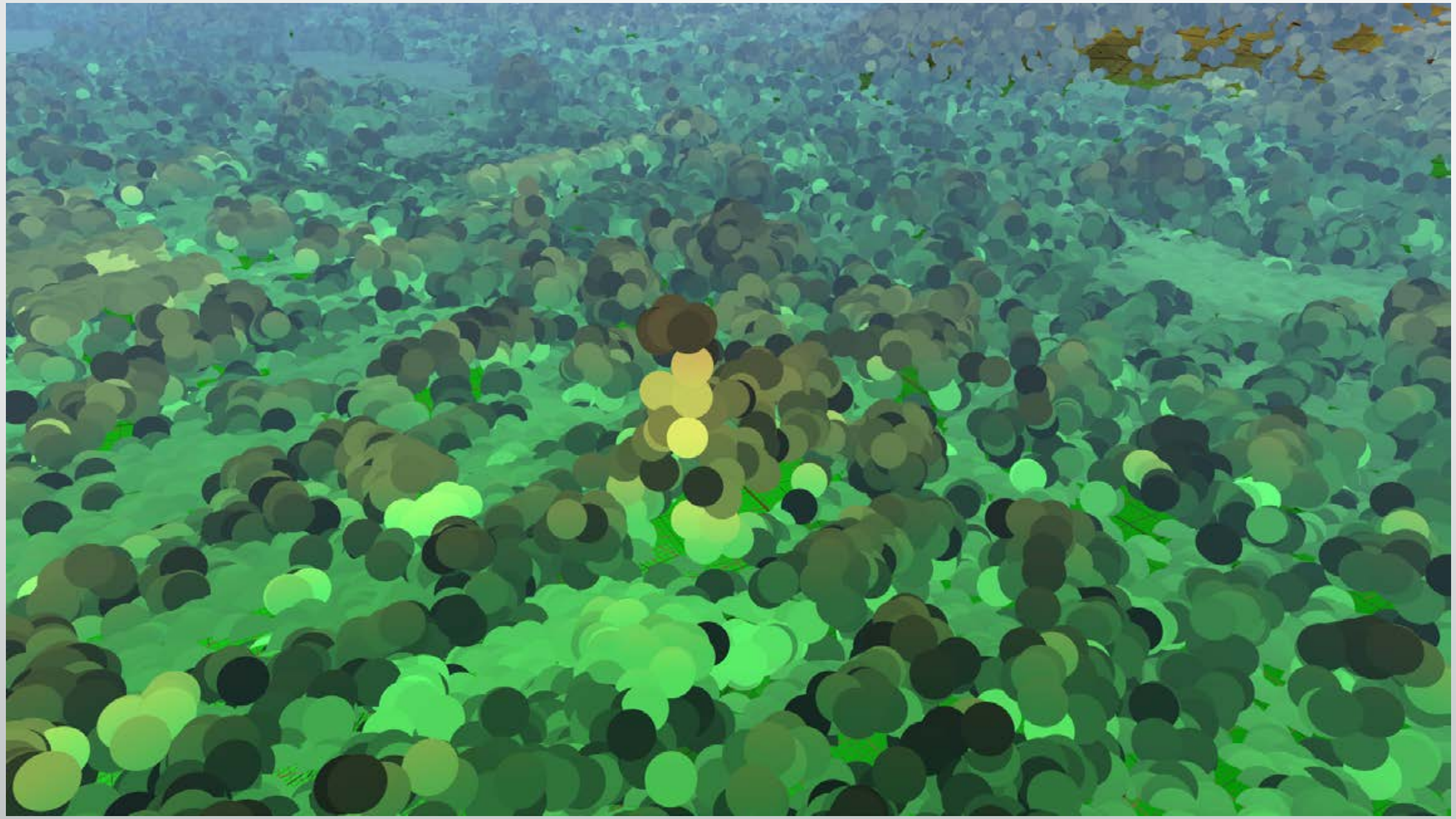
Point Cloud is Fragmented



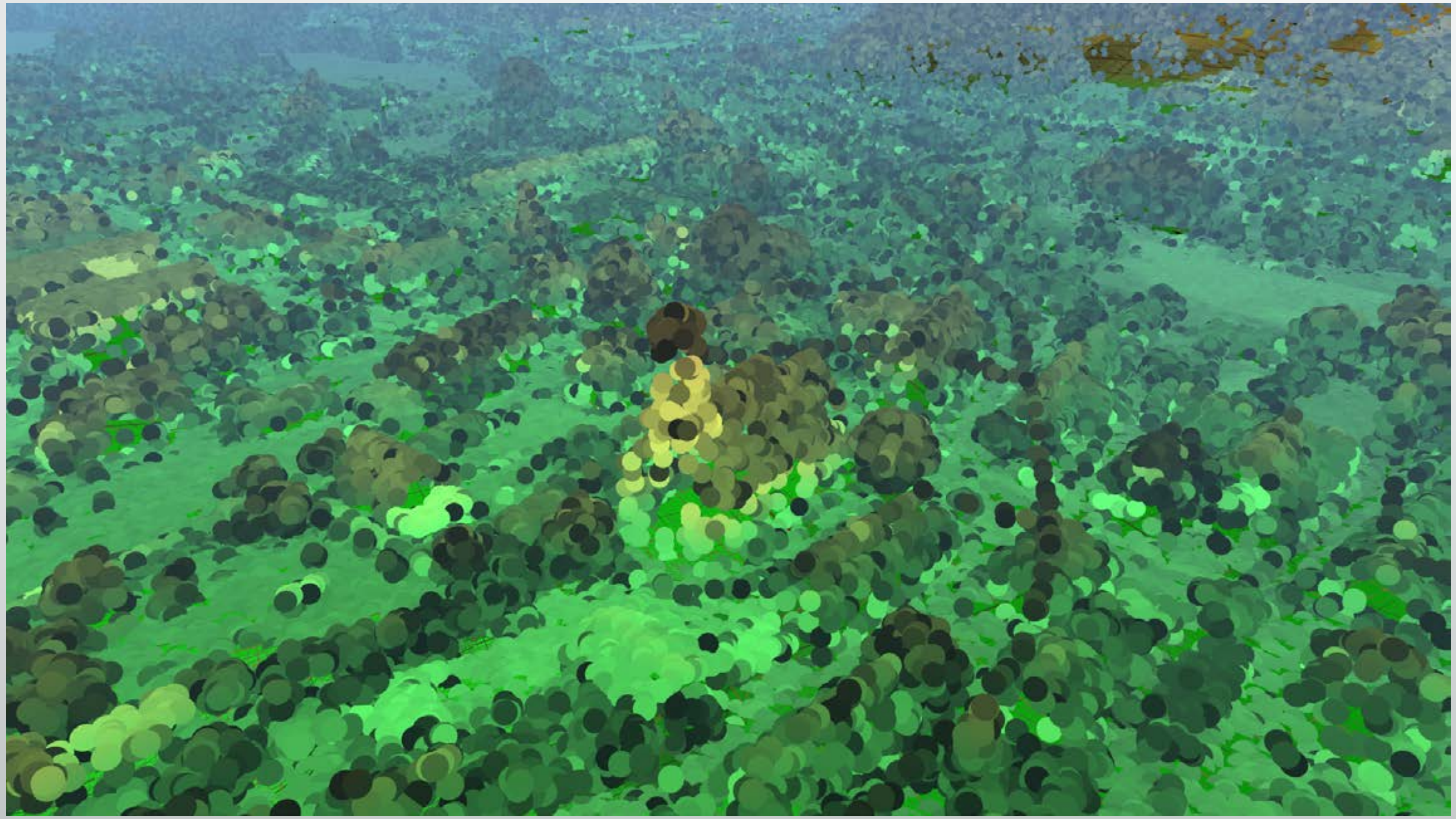
Data Handling #2: Hierarchy – Level of Detail

Hierarchy – Level 1

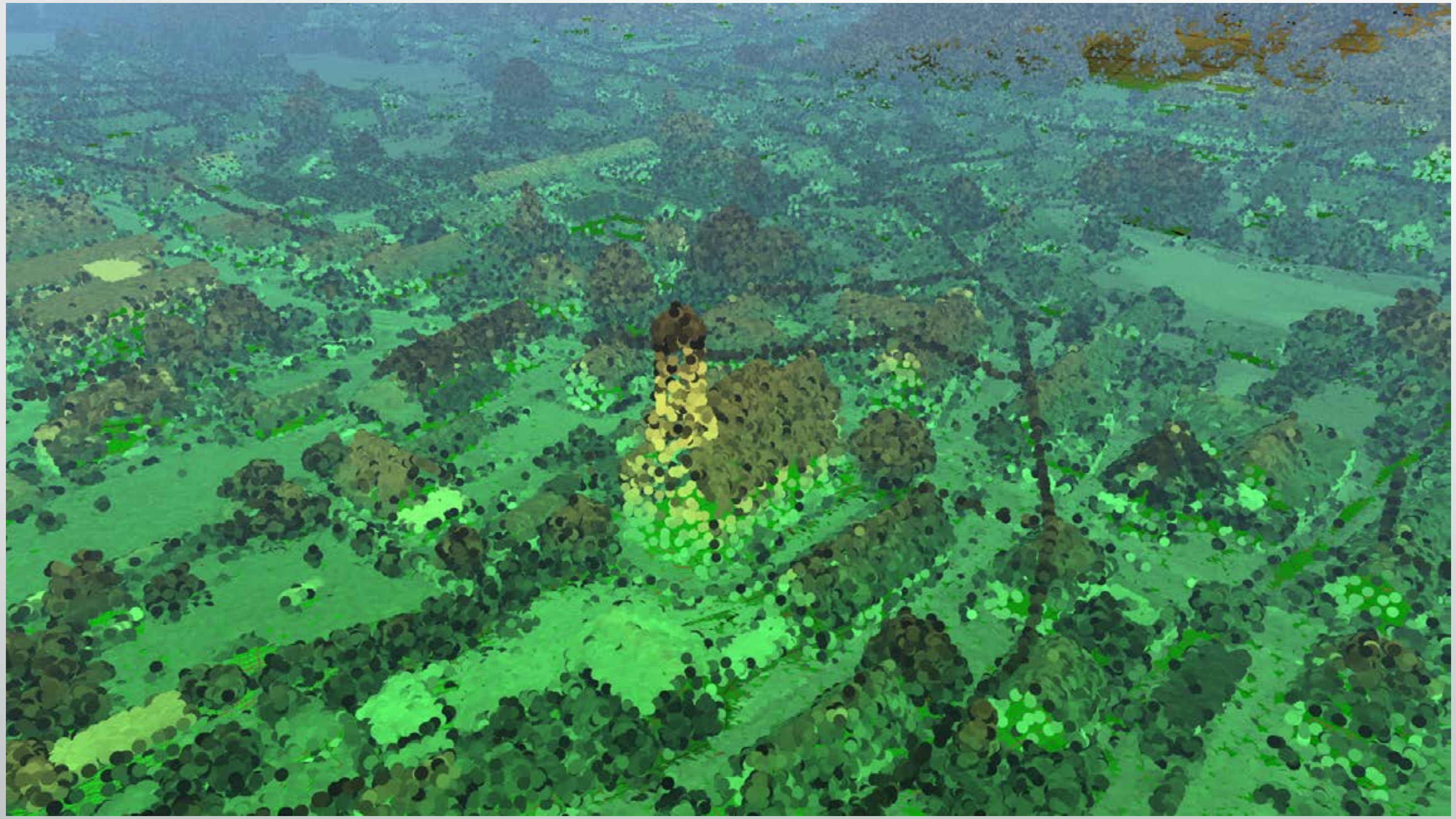
Hierarchy – Level 2



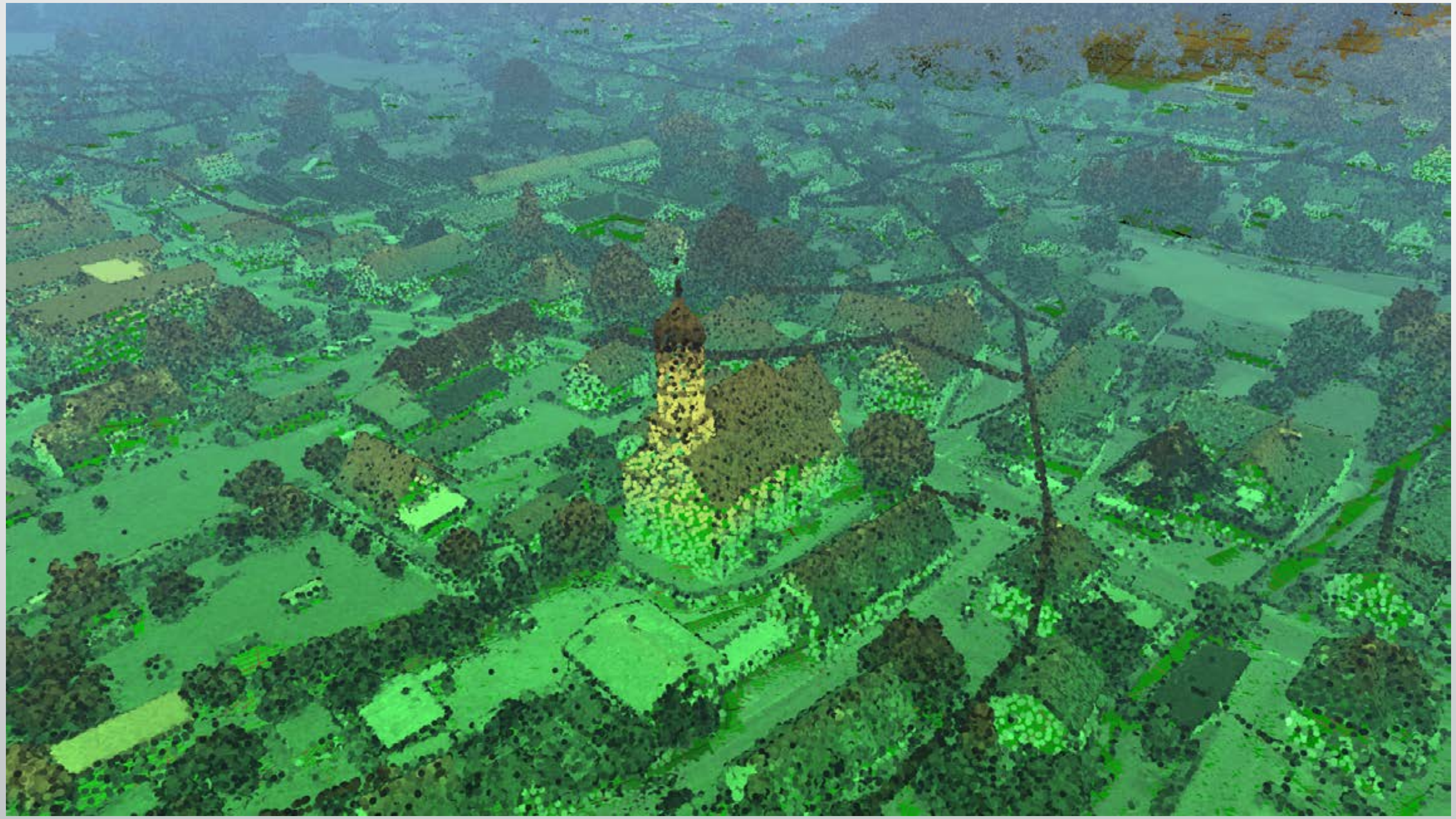
Hierarchy – Level 3



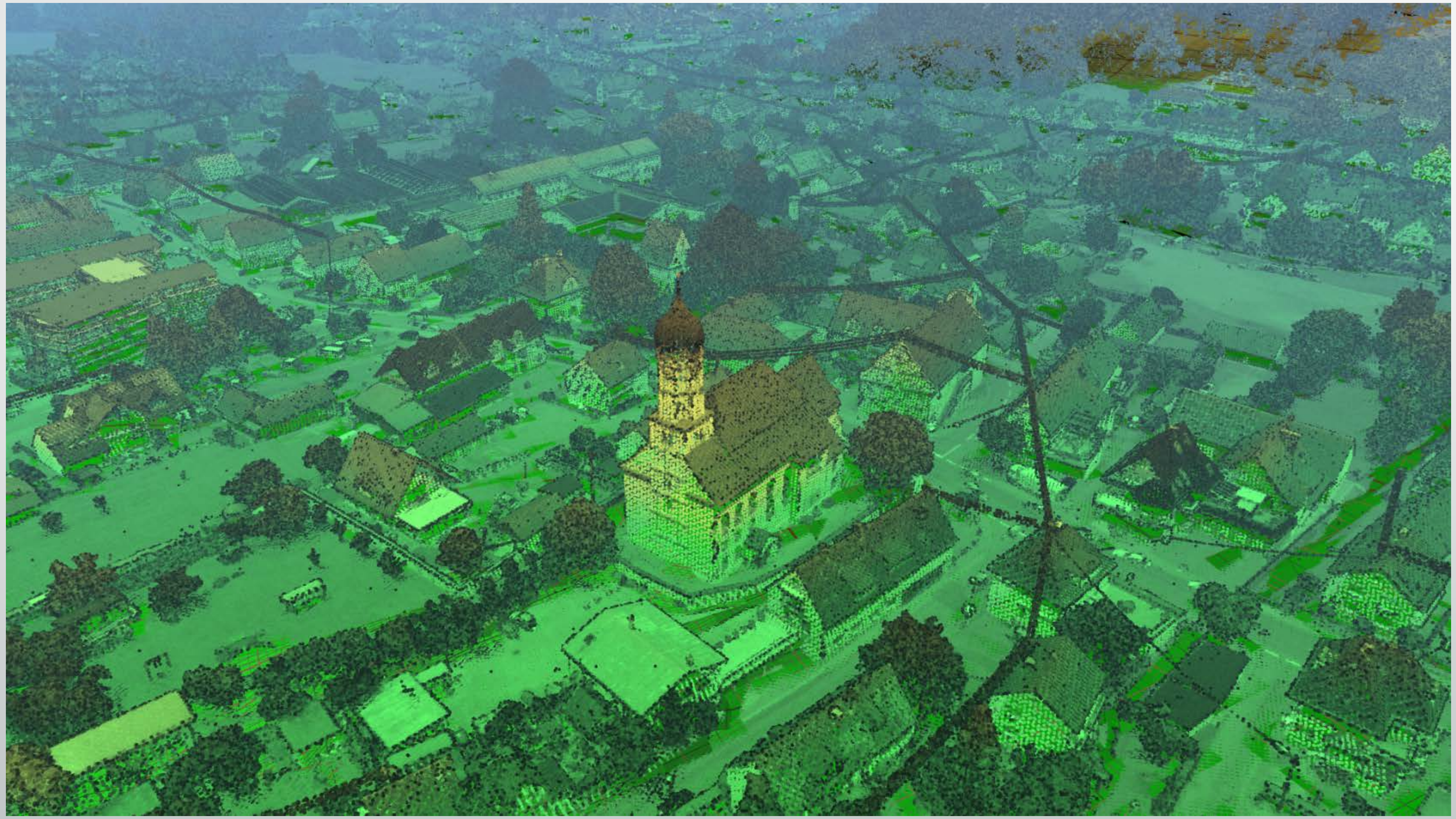
Hierarchy – Level 4



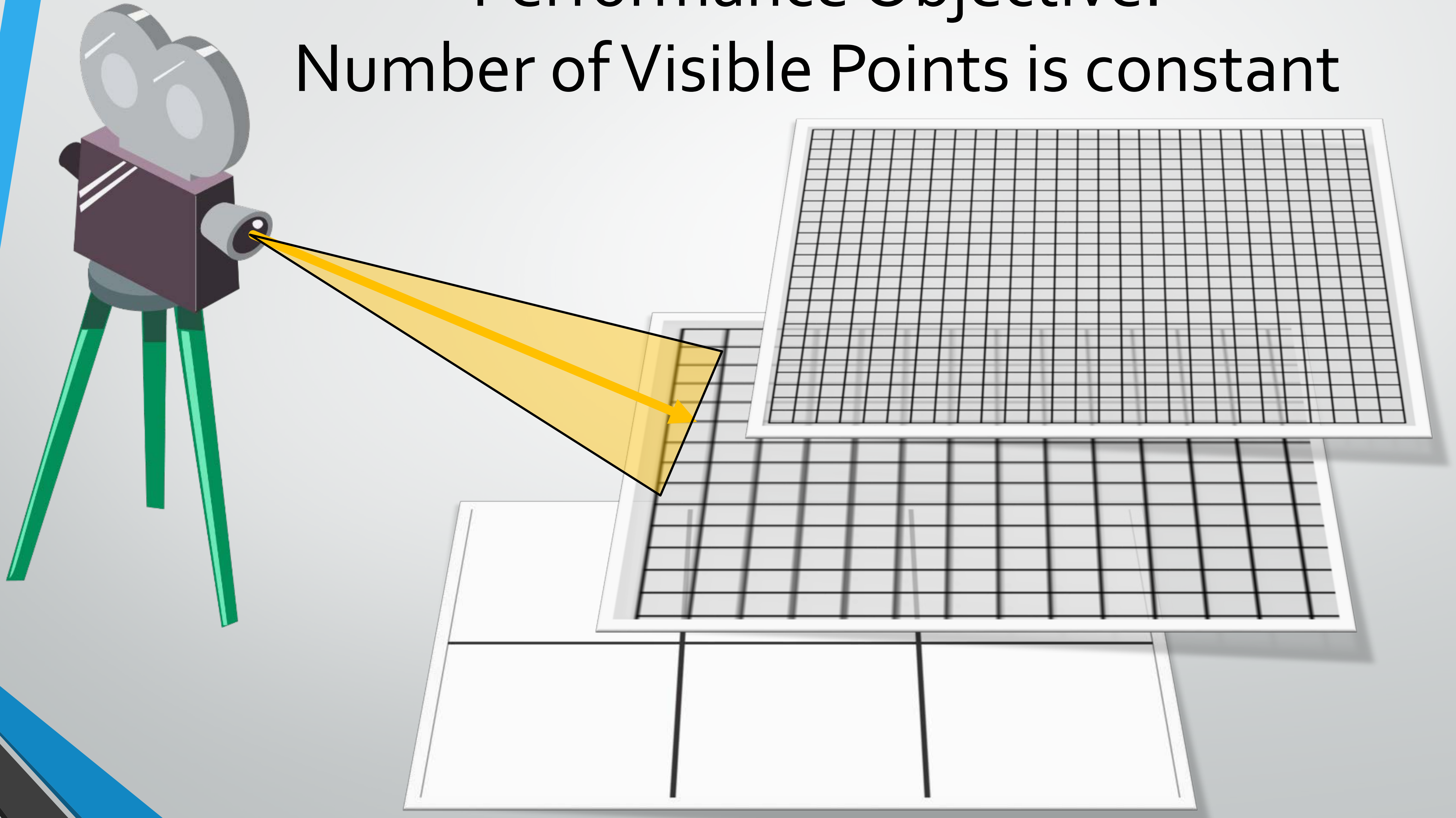
Hierarchy – Level 5



Hierarchy – Level 6



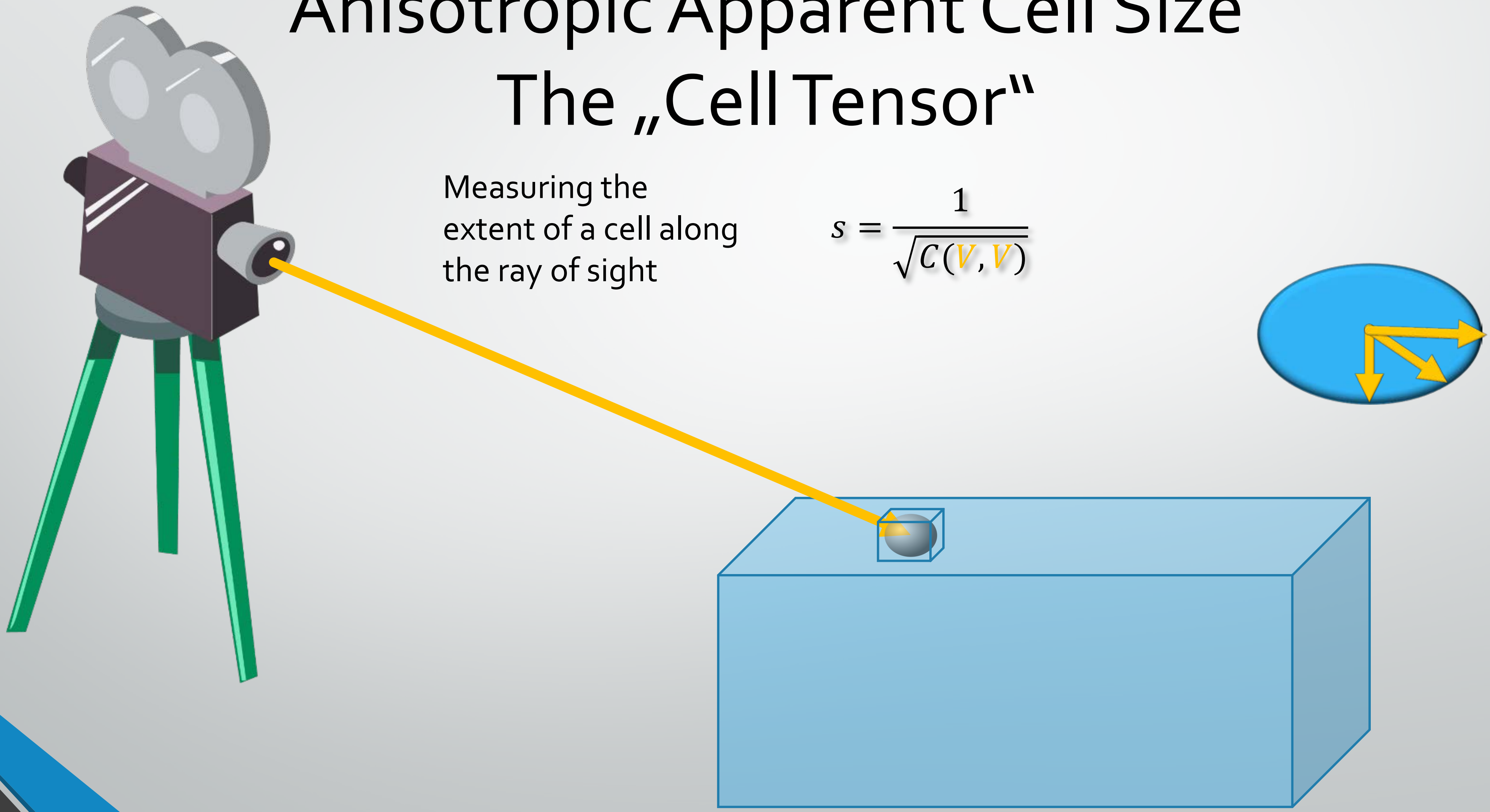
Performance Objective:
Number of Visible Points is constant



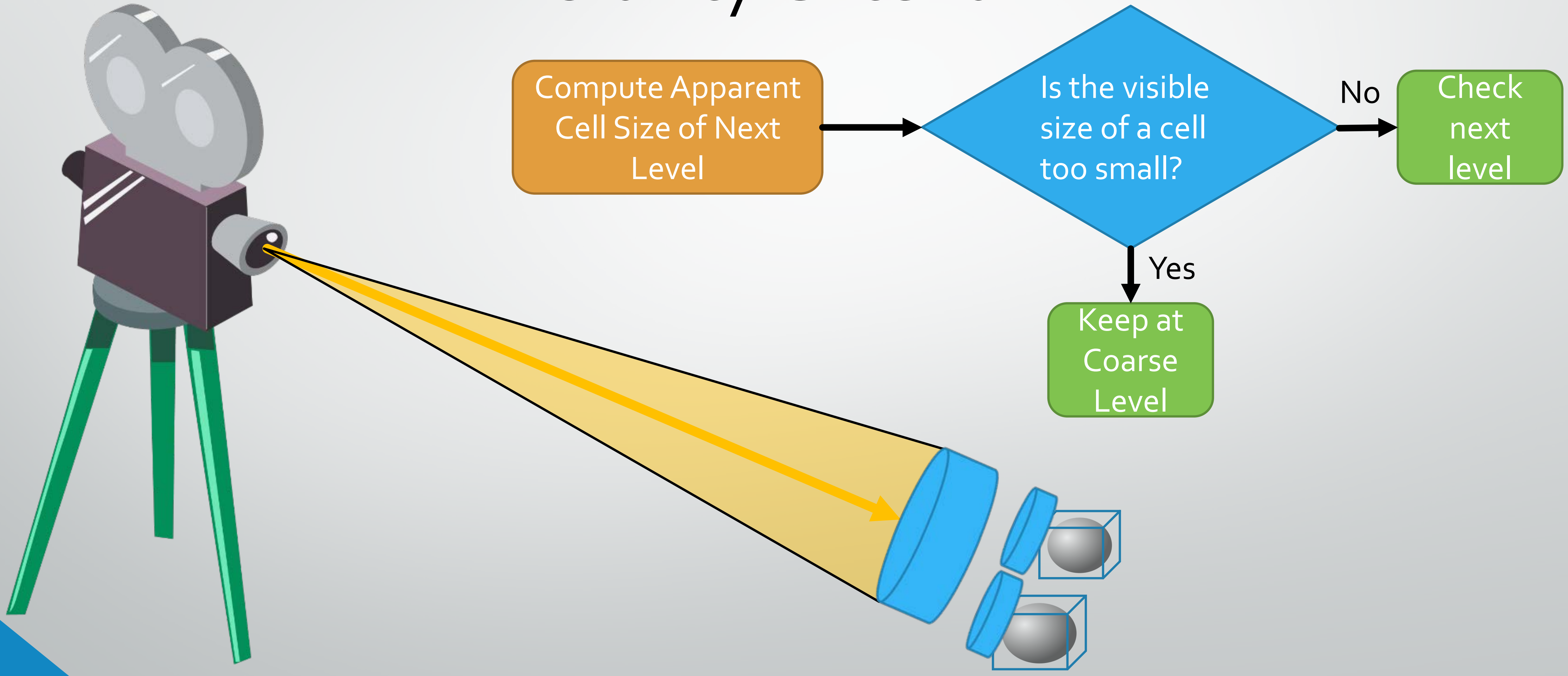
Anisotropic Apparent Cell Size
The „Cell Tensor"

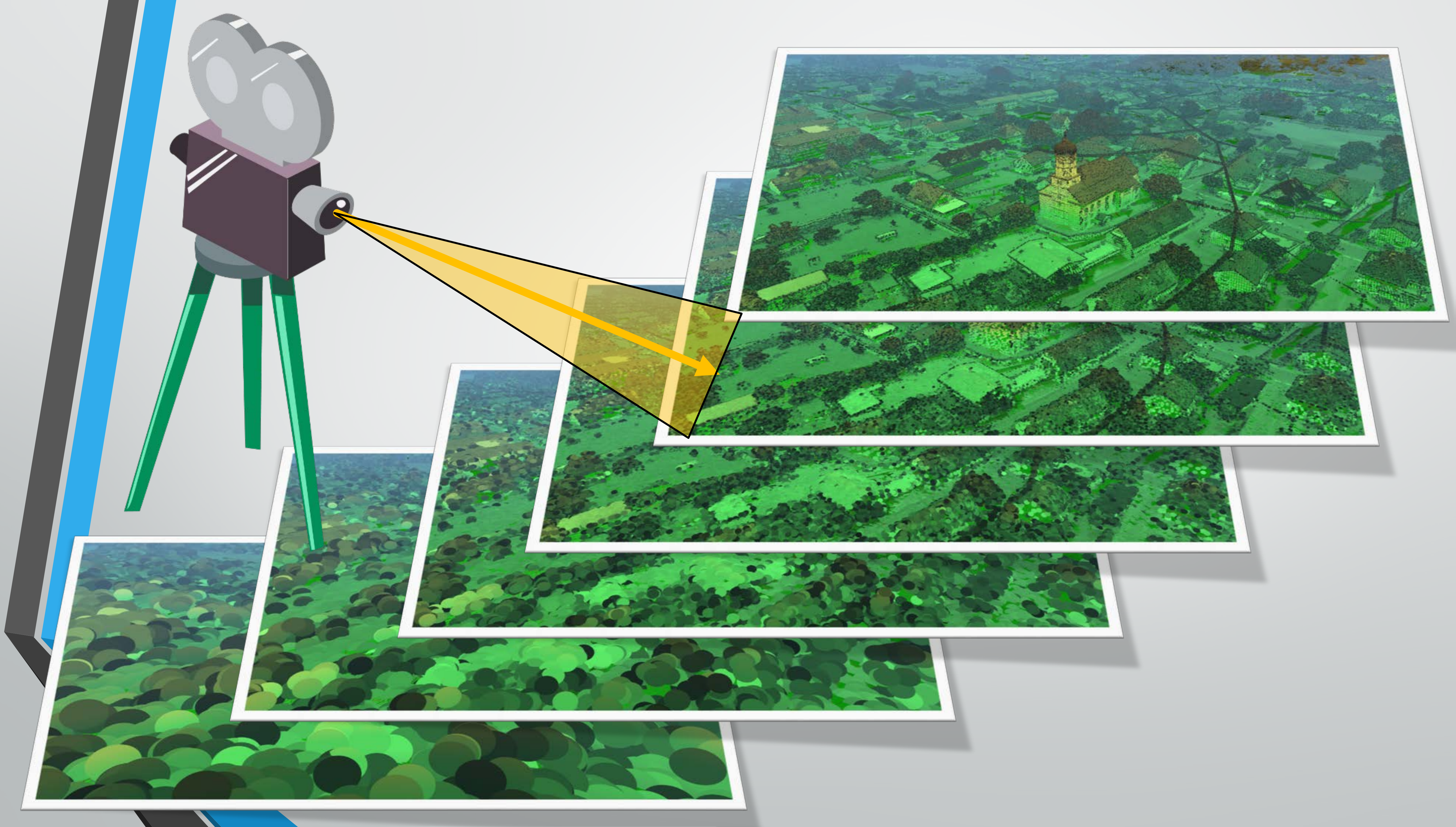
Measuring the extent of a cell along the ray of sight

$$s = \frac{1}{\sqrt{C(V,V)}}$$

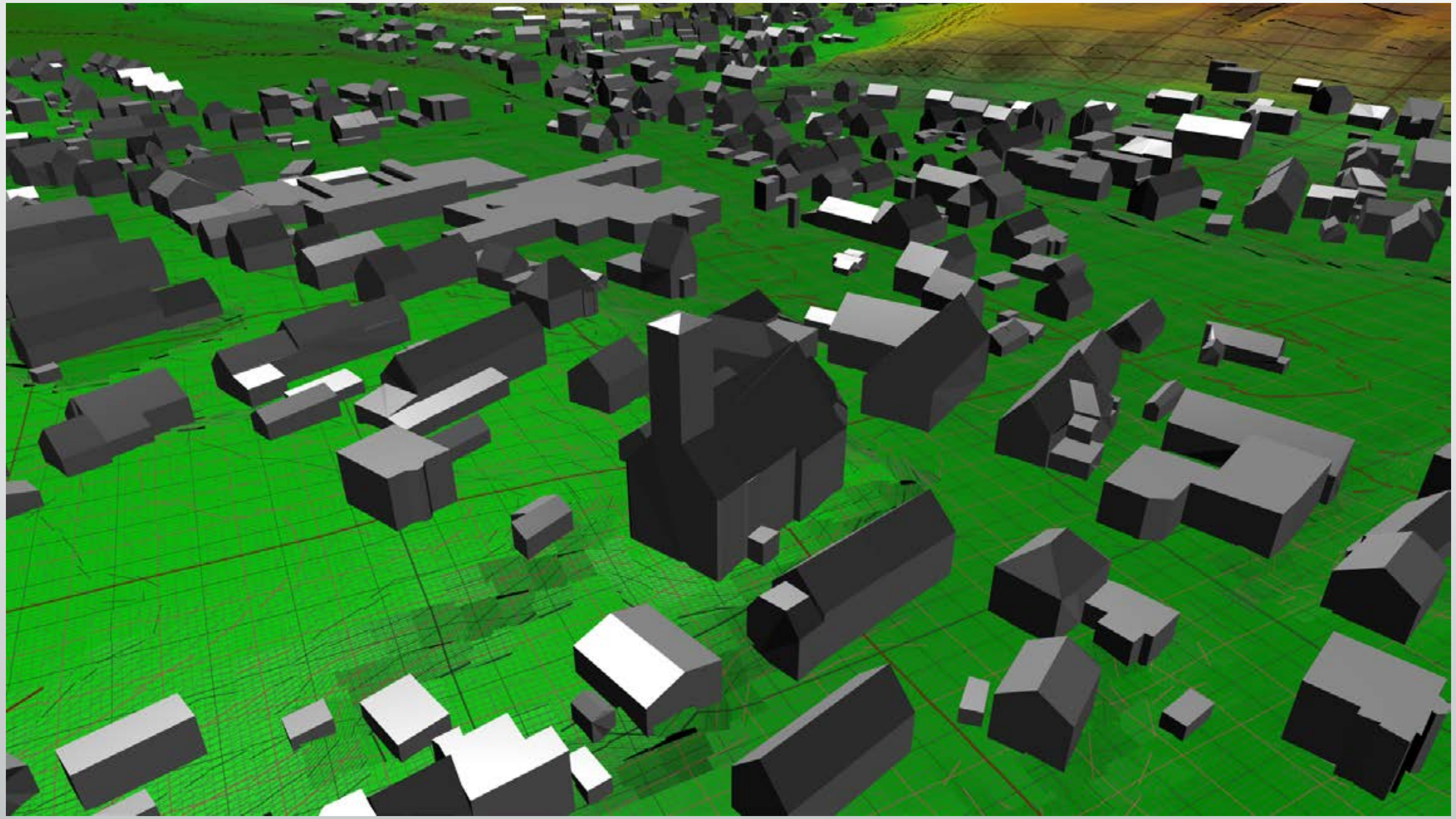


Visibility Criteria

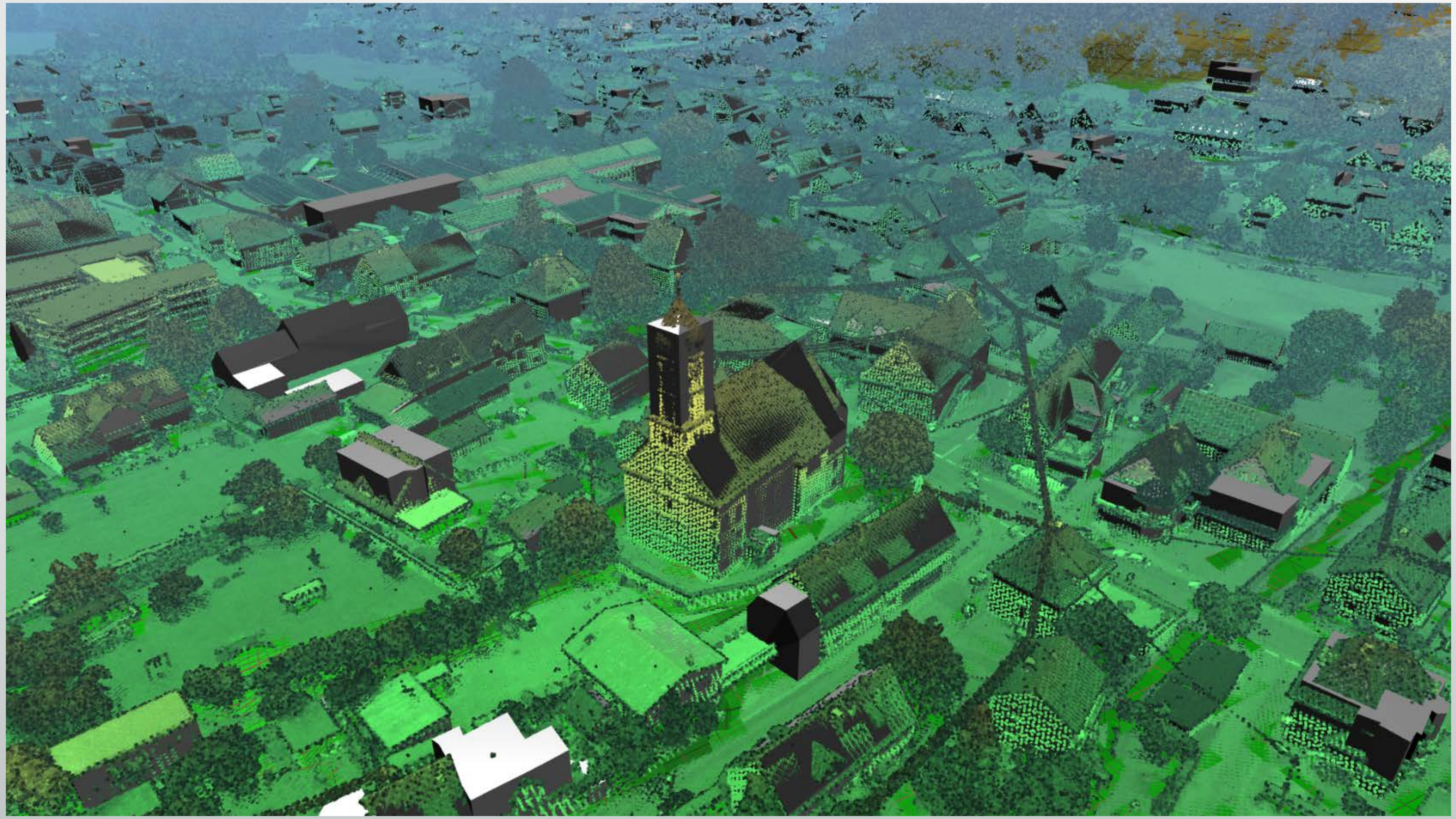




Integrate with Geometries (e.g. Triangular Surfaces)

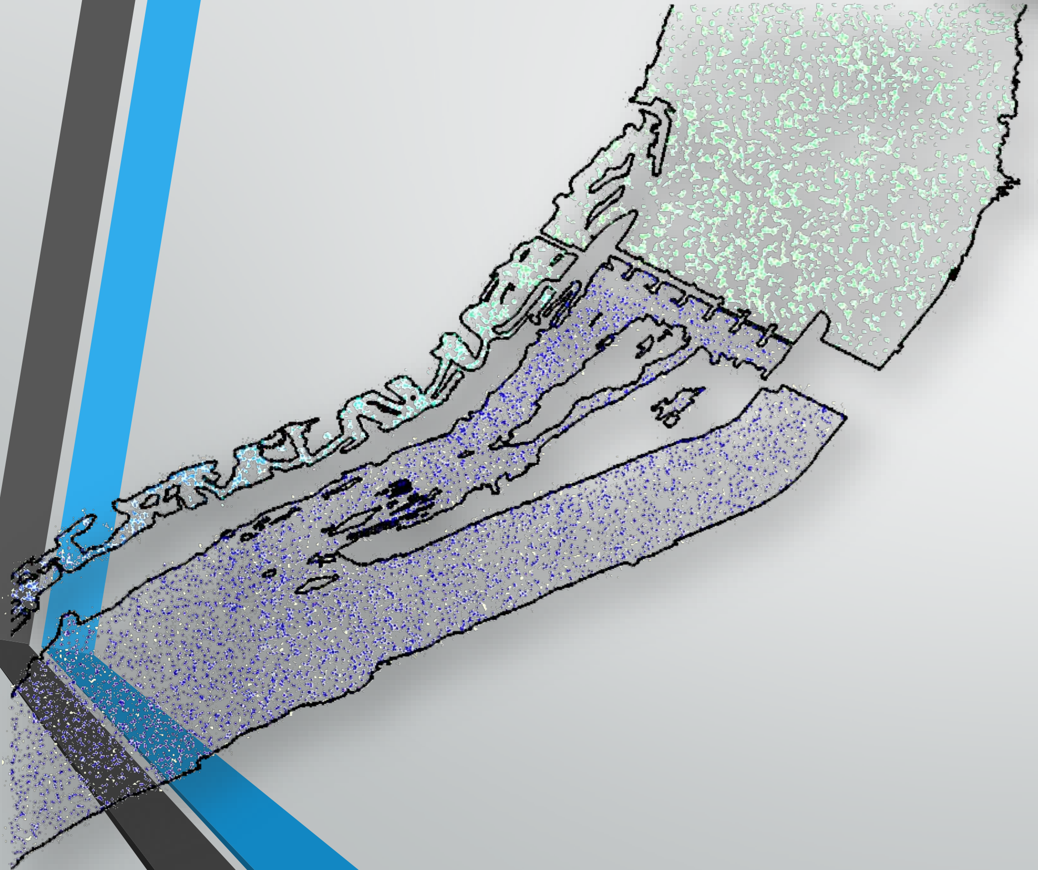


Integrate with Geometries (e.g. Triangular Surfaces)

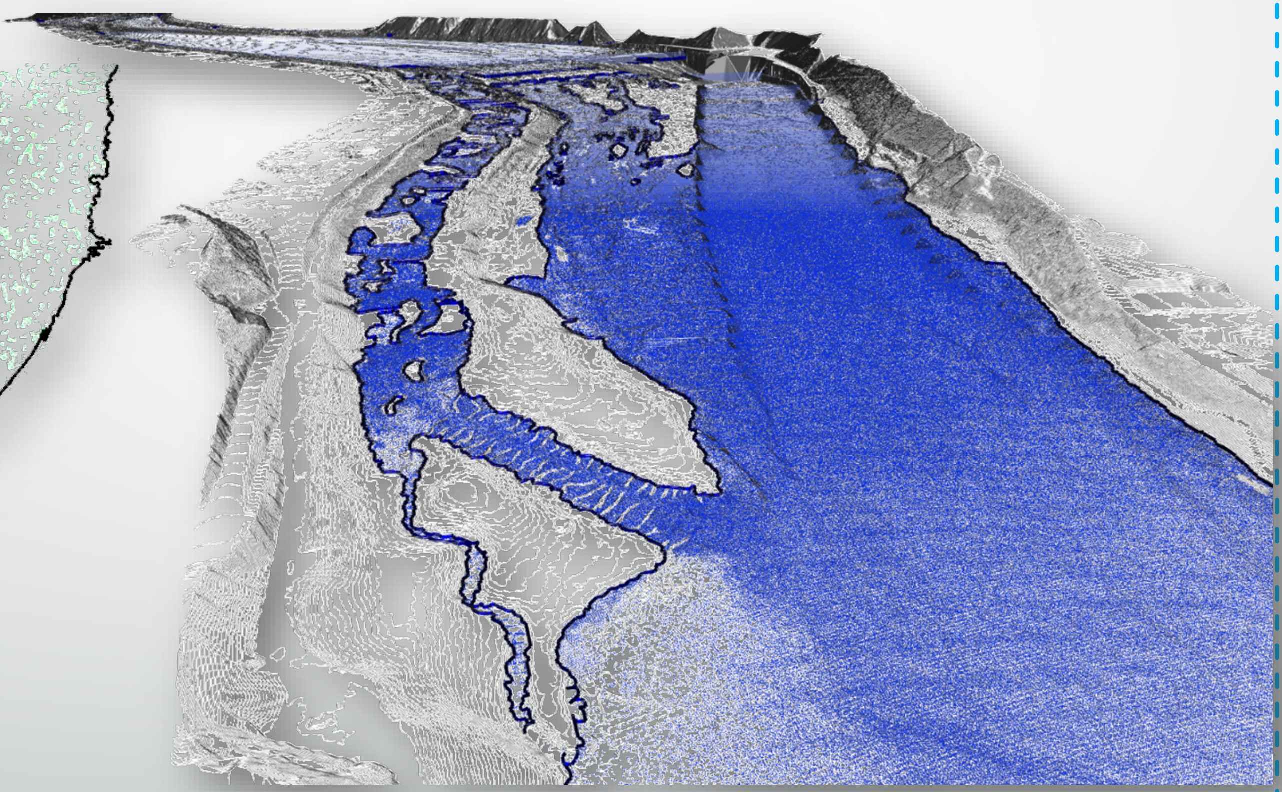


Data & Visualization fusion: 1D, 2D, 3D, ...

Extraction of boundarywater-surface

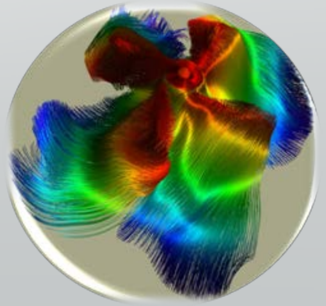


Explicit LinesContour



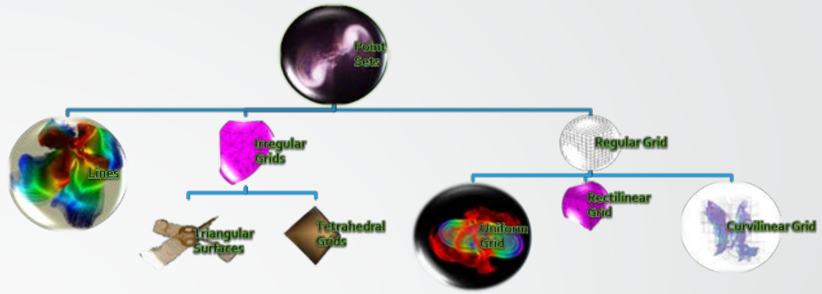
The Tool Approach
“Specific Problems need specific Solutions”

Point Cloud Data	Triangular Mesh	Lines	?
↓	↓	↓	↓
Display as Points	Display as Surface	Display as Lines	Display as ??



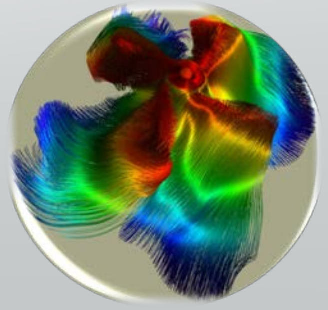
The Framework Approach

Generic Methods to avoid reinventing the wheel



Point Cloud Data   Triangular Mesh   Lines   ?

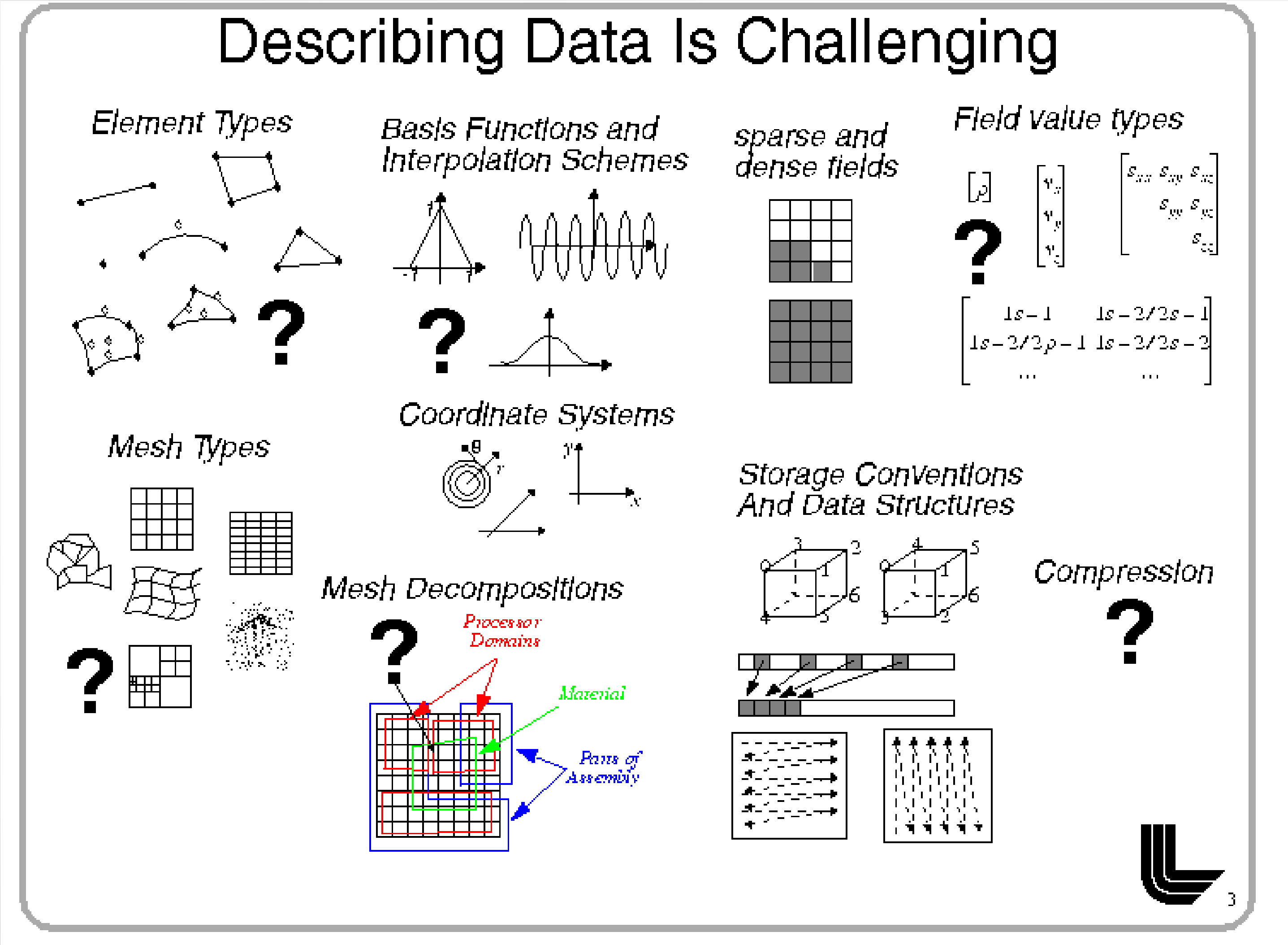
Display as Points   Display as Surface   Display as Lines   Display as ??



Unifying Application Cases as Fiber Bundles

Organising Data for Massive Amounts of data, fast processing and visualization

Inspired by: Differential Geometry, Topology, Geometric Algebra



Thanks to Mark Miller, LLNL

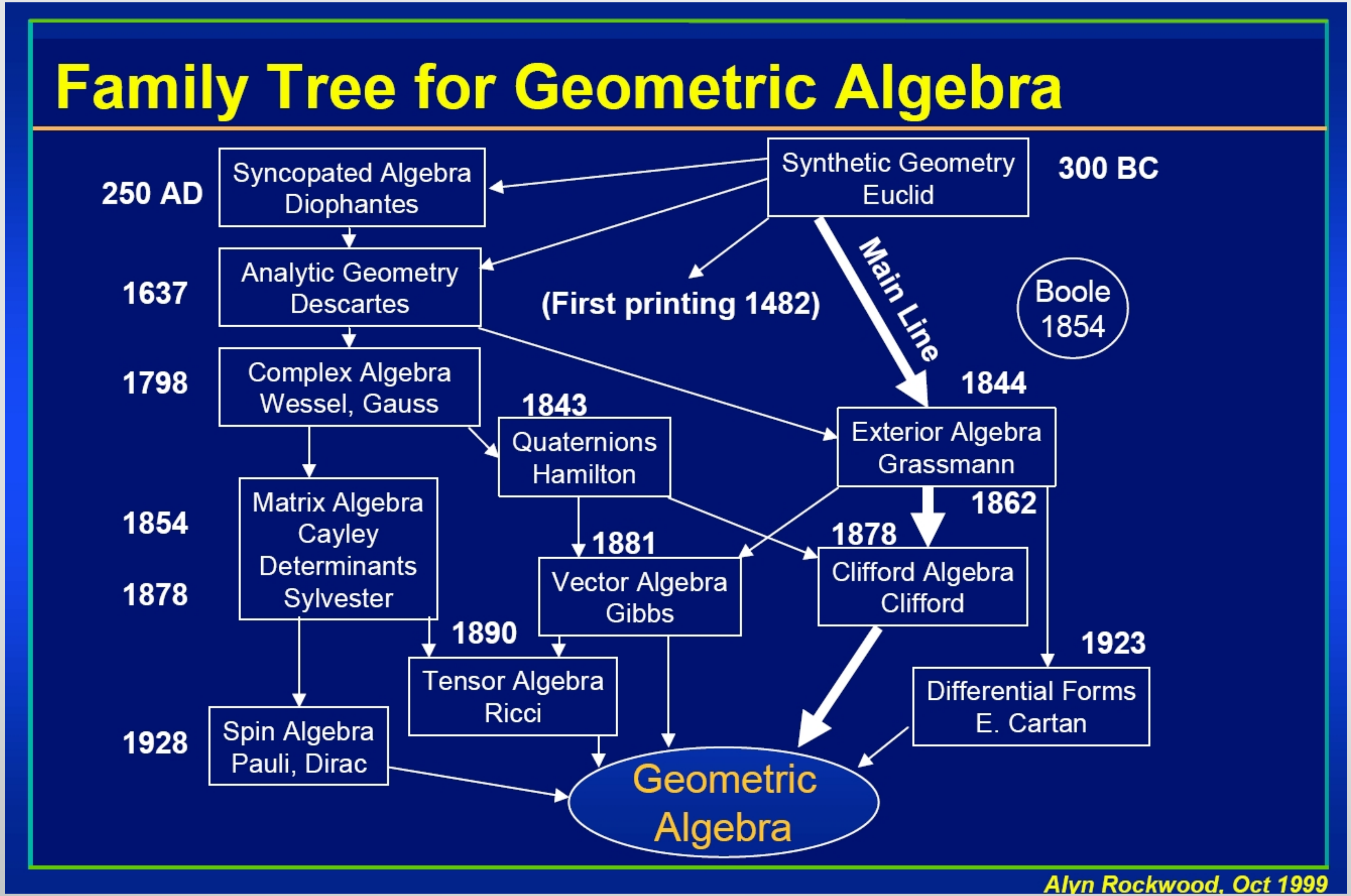
Challenge of a Common Data Model

"The proper abstractions for scientific data are known. We just have to use them."

D. M. Butler & S. Bryson

Vector-Bundle Classes form Powerful Tool for Scientific Visualization

Computers in Physics, Vol. 6, No 6., Nov/Dec 1992



1966-2005: David Hestenes (Arizona State University) recovers geometrical interpretation of clifford algebra as “geometric algebra”

Mathematics for Visualization

Topology

- Discretization schemes, combinatorial structure, relational information

Differential Geometry

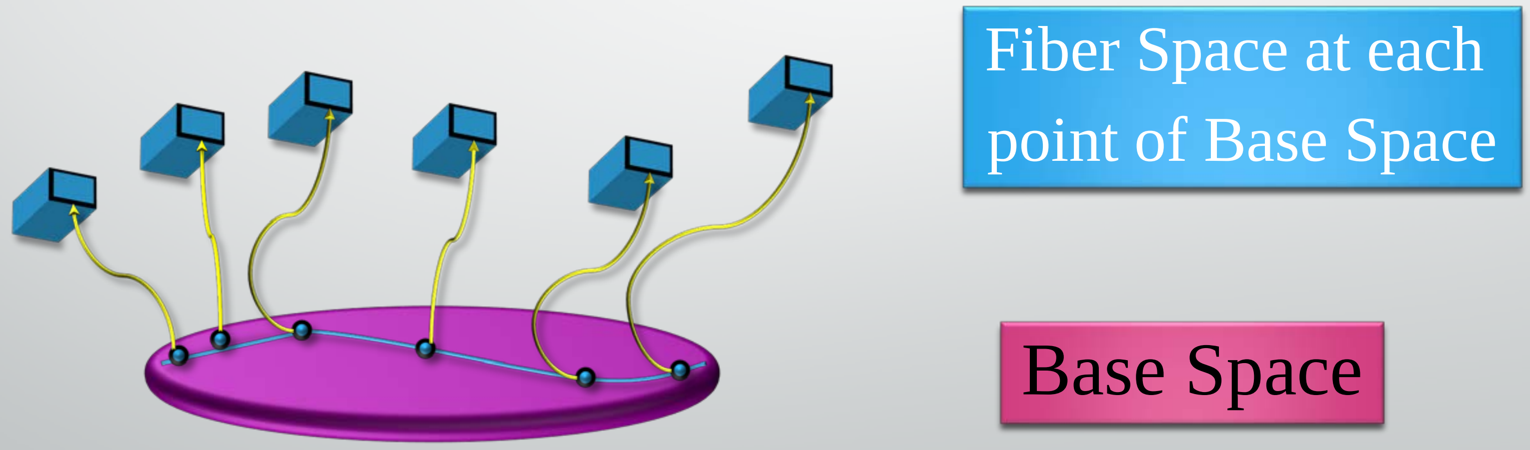
- Coordinate representations, transformations, differential operators, tensor algebra

Geometric Algebra

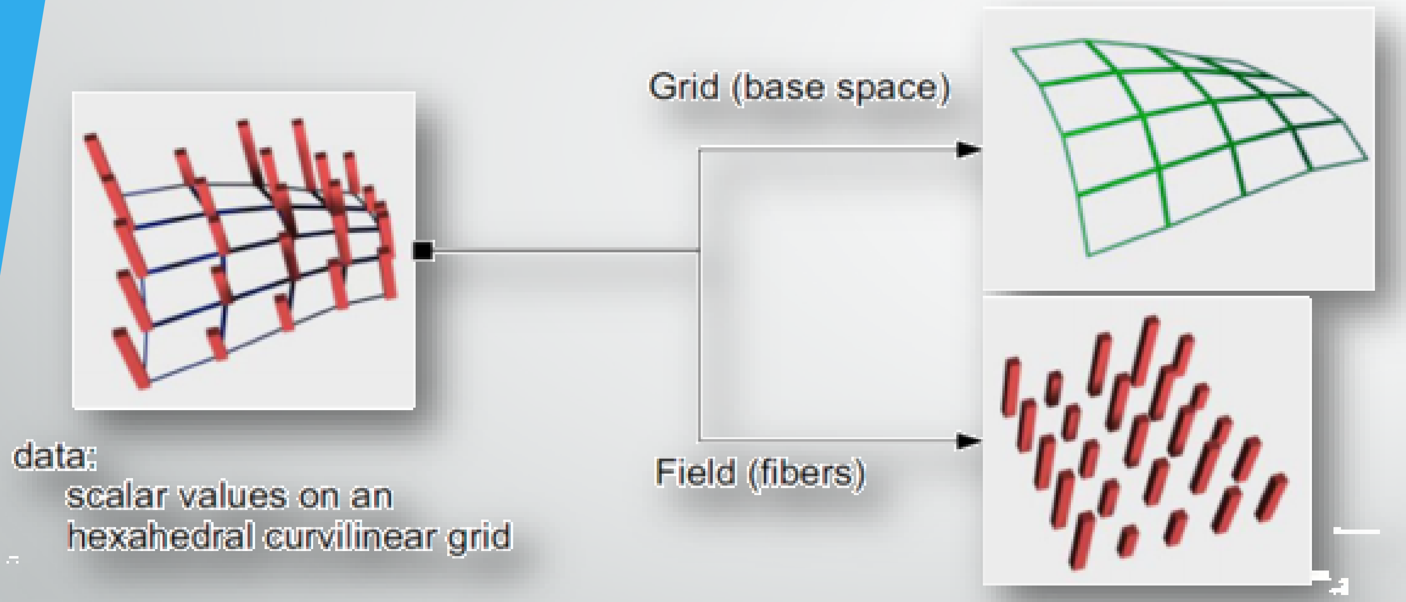
- N-dimensional Rotations, navigation, data analysis, feature extraction, spinor formalism, generalized quaternions, mimetic operators

Fiber Bundle Data Model

- Is a generic approach to handle a wide range of data types used for scientific visualization
- Basic concept: Base space maps to fibers



Geometric Algebra in the Fiber Bundle



Base-Space operations:

- Dealing with large data
- Differential operators
- This is where Geometric Algebra „may life".

→ Operations on the manifold (possibly a vector space)

Fiber-Space elements:

- This is where Geometric Algebra „lives"
- Zoo of multivectors and tensors

→ Operations on the tangential space and powers of it (always vector space)

Mathematical Notation

- Concept of a Manifold *M* with Tangential Spaces $T_p(M)$ at each point $p \in M$

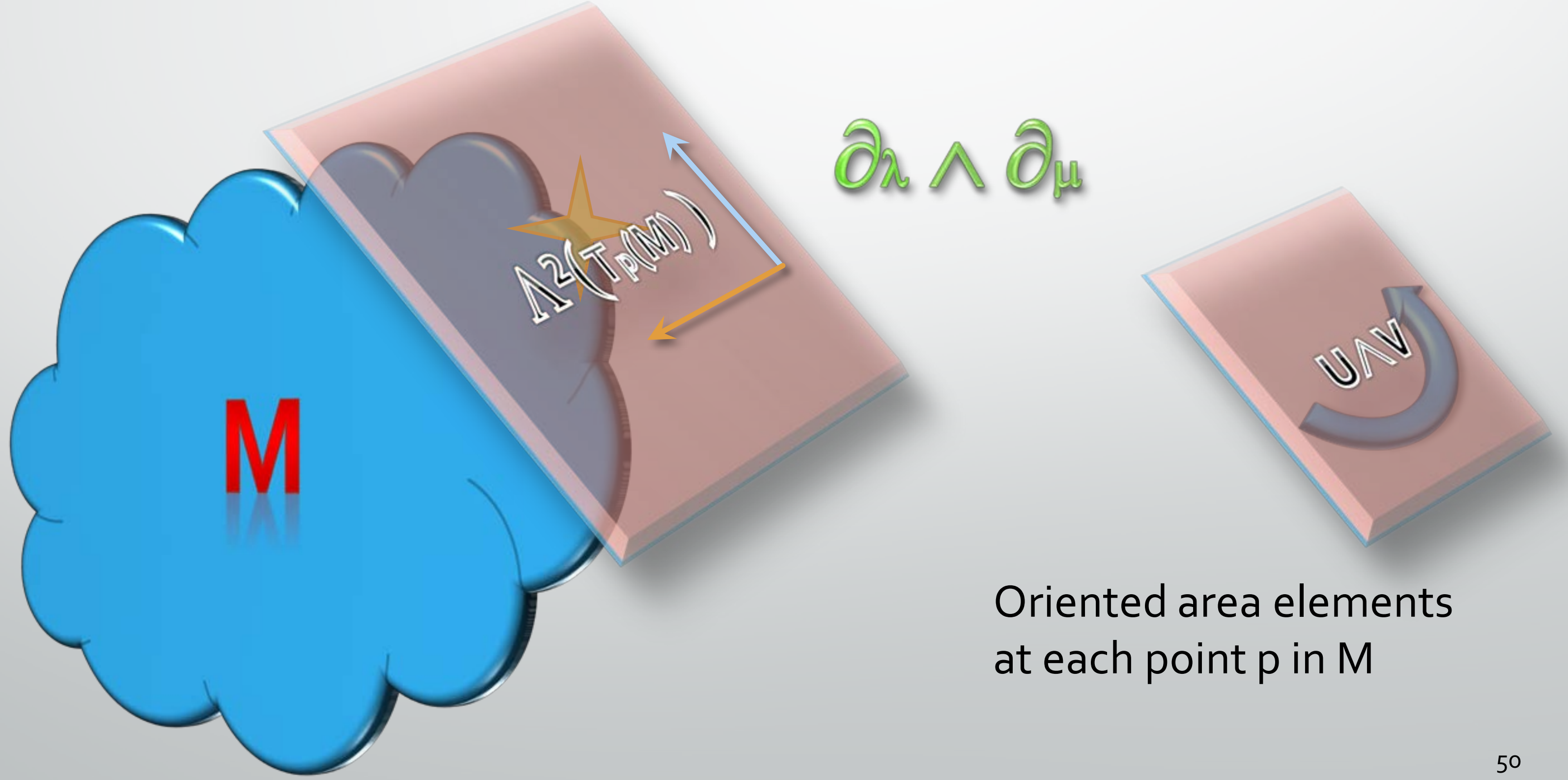
M is not a vector space
T is a vector space
(at each point p of M)

Spun by derivatives d/dλ

Grassmann Algebra on $T_p(M)$

- $\wedge: T_p(M) \times T_p(M) \rightarrow \Lambda^2(T_p(M))$

  $u,v \qquad \Rightarrow u \wedge v$ where $u \wedge v = -v \wedge u$



Oriented area elements
at each point p in M

Data Type Classification

Base Space

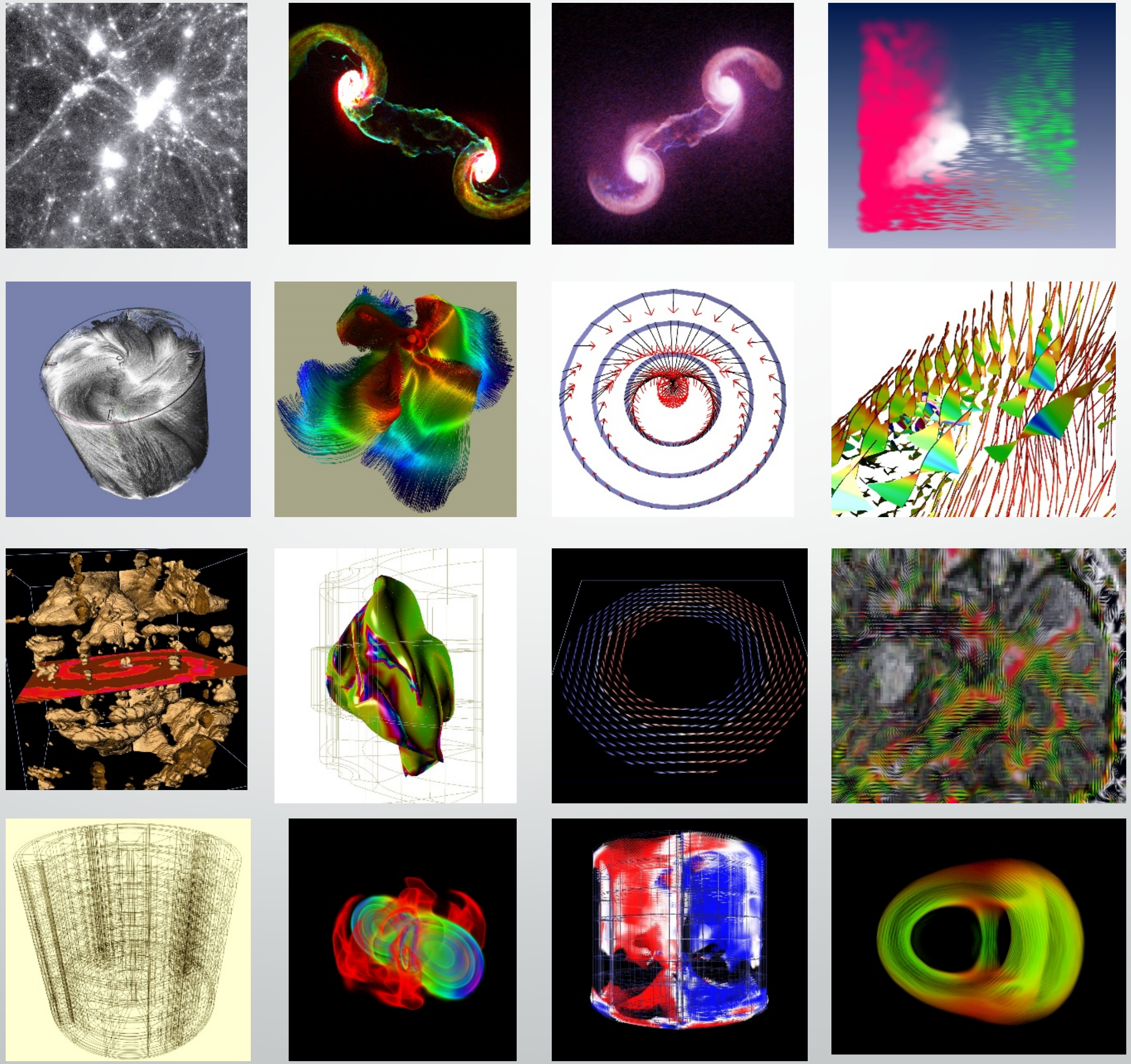
- "Structured" Grids
  - Uniform
  - Curvilinear
  - Multiblock
  - Refinement
- "Unstructured" Grids
  - Particle Sets
  - Surfaces
  - Line sets

Fiber Space

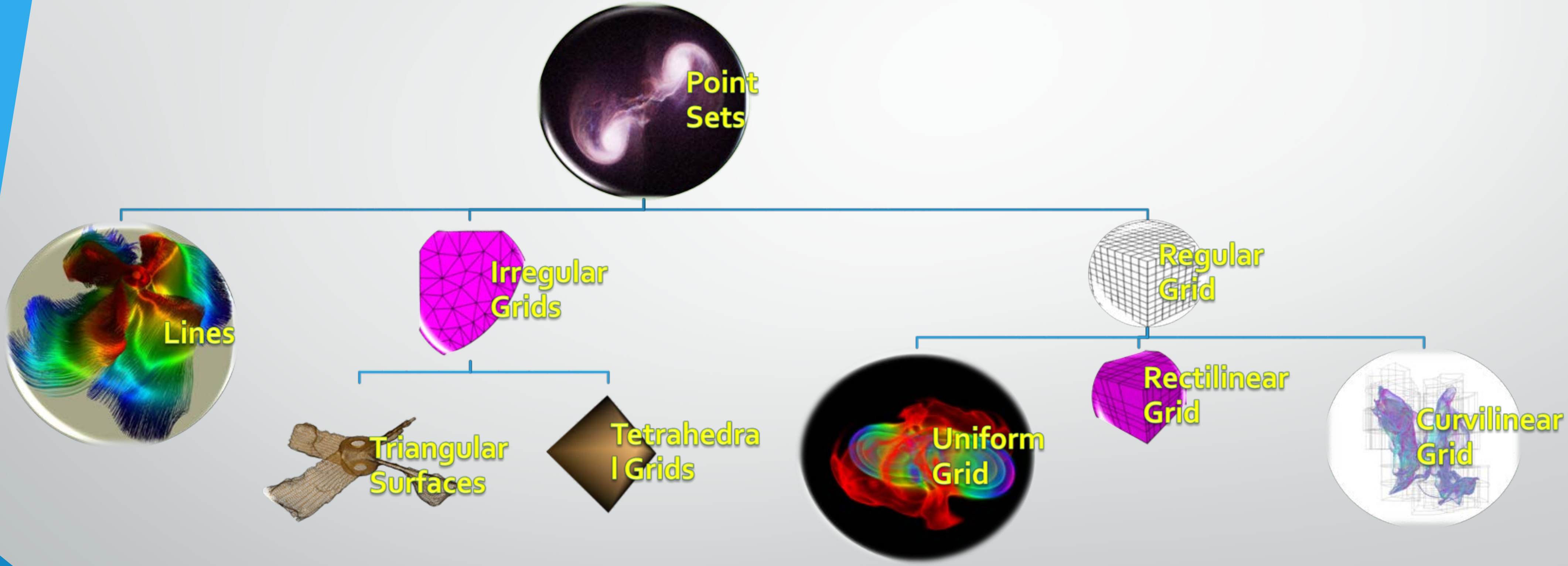
- Scalar Fields
- Vector Fields
  - Bivector fields
  - Co-vector fields
  - Multivector fields
- Tensor Fields
  - Symmetric / Asymmetric
  - 2^{nd} order, 3^{rd} order, 4^{th} order…

Fiber: 0D 1D 3D 6D

Base: 0D 1D 2D 3D

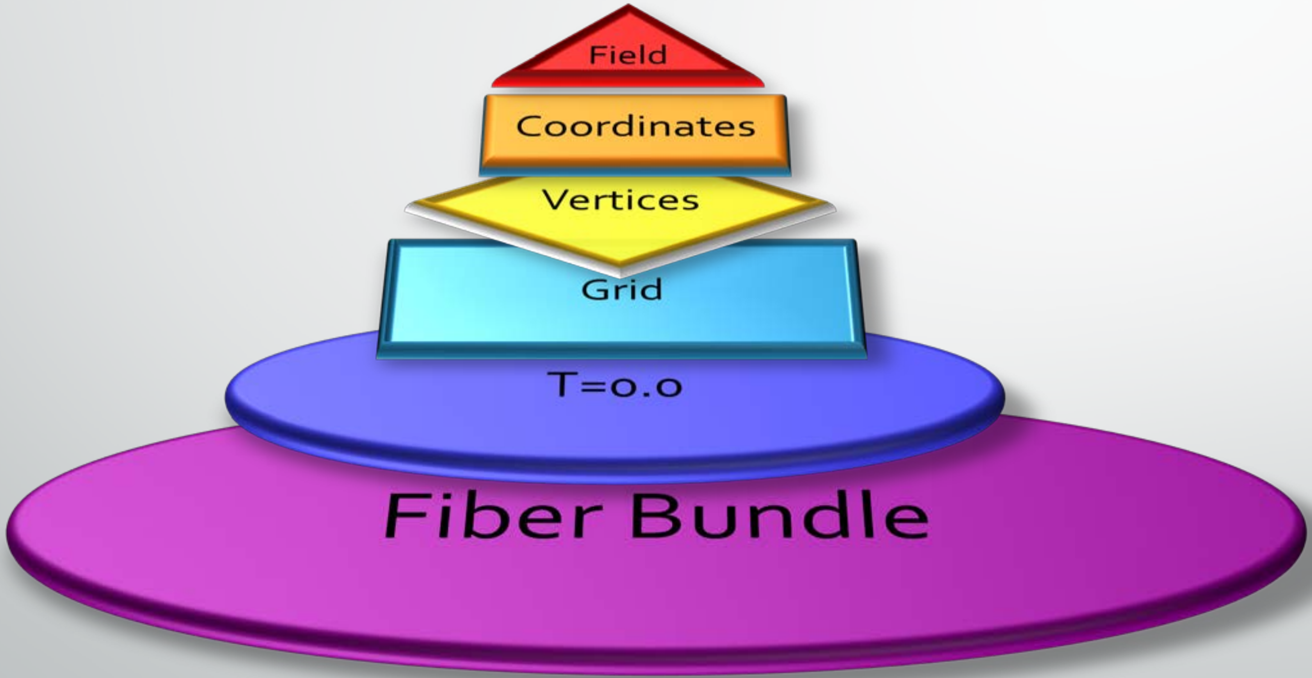


Hierarchy of Grid Types



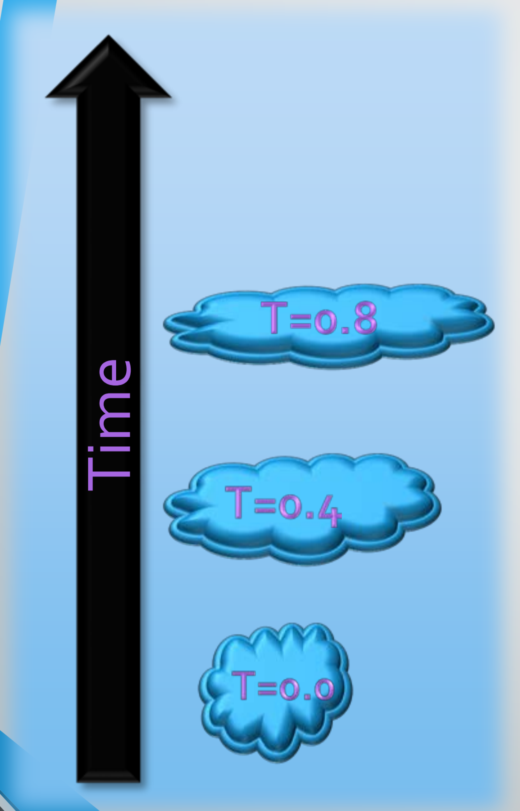
The F5 Fiber Bundle Data Model

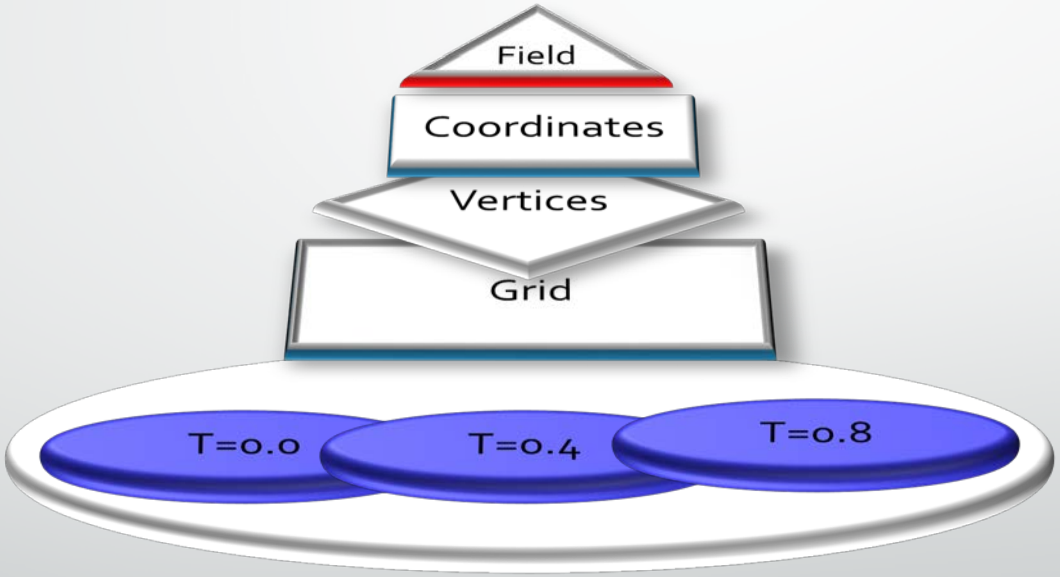
Casts data into hierarchy:



1. Field
2. Representation
3. Skeleton
4. Grid object
5. (Time) Slice
6. Bundle

Lowest Level: Fiber Bundle over a Parameter Space





1. Field
2. Representation
3. Skeleton
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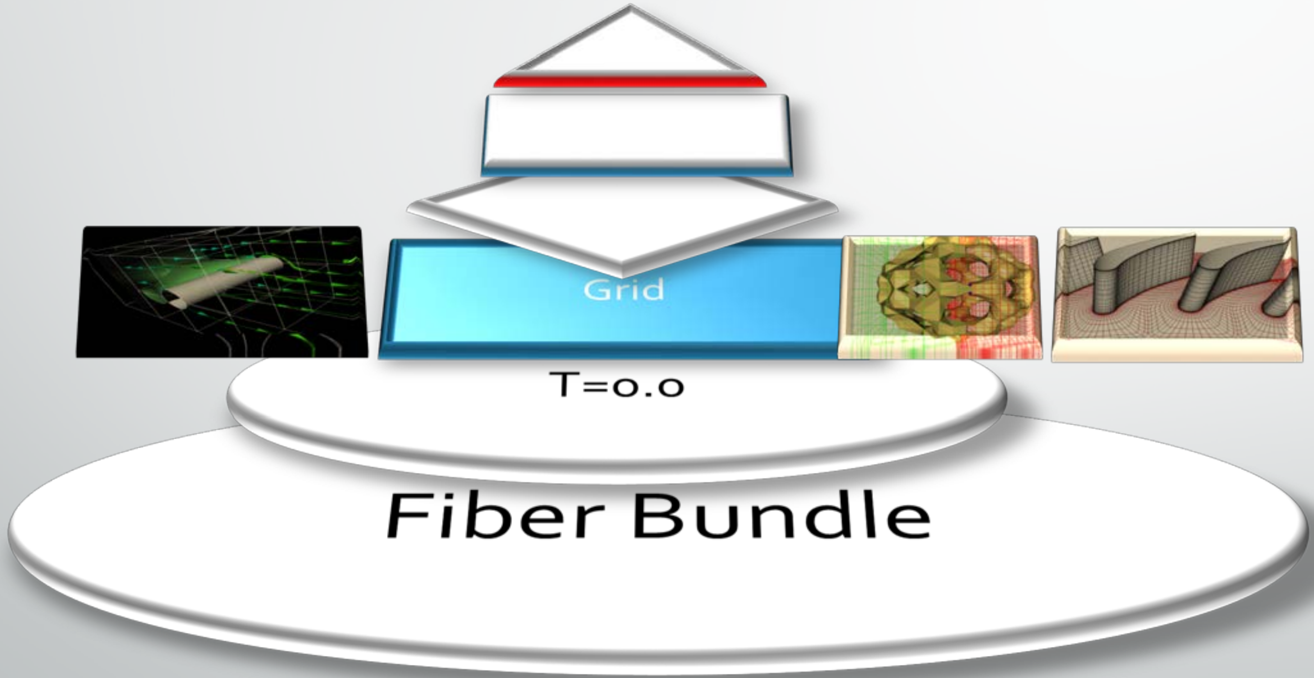
Grid: A geometric entity



1. Field
2. Representation
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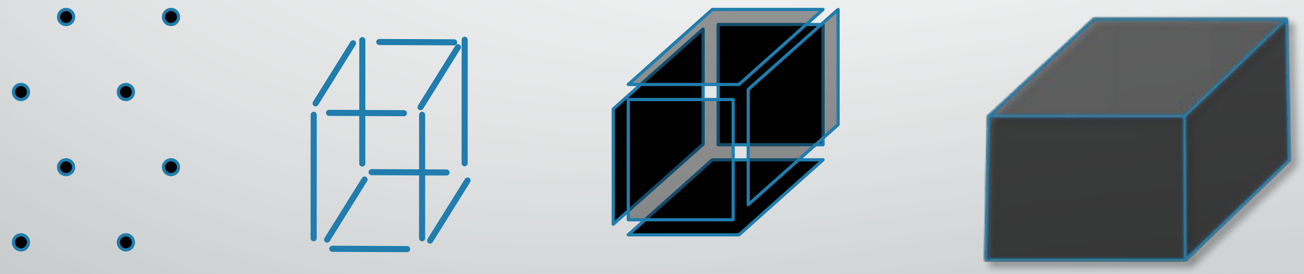
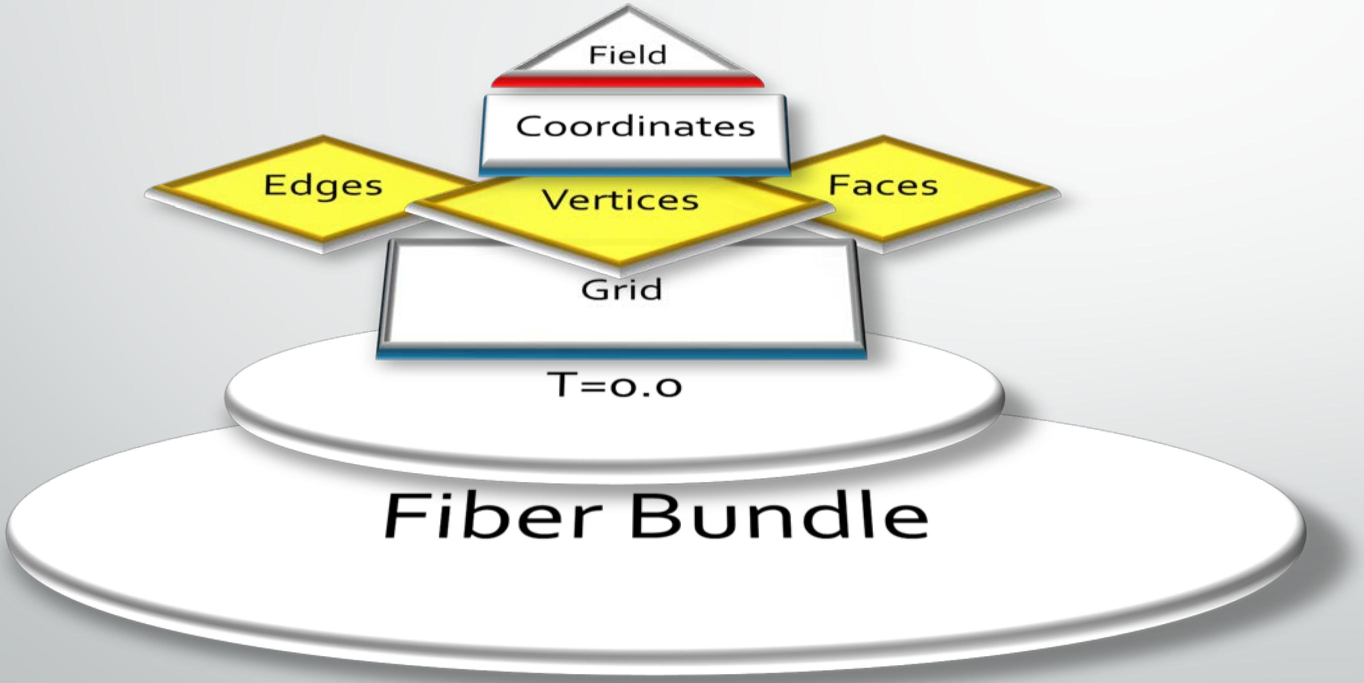
Topology: cw-Complex

- Discretized n-dimensional Manifold
- Concept of k-cells with adjacency
- Hierarchy of k-Skeletons, k=0...N



0-cell: Vertices   1-cell: Edges   2-cell: Faces   3-cell: simplexes

Topology: k-Skeletons



1. Field
2. Representation
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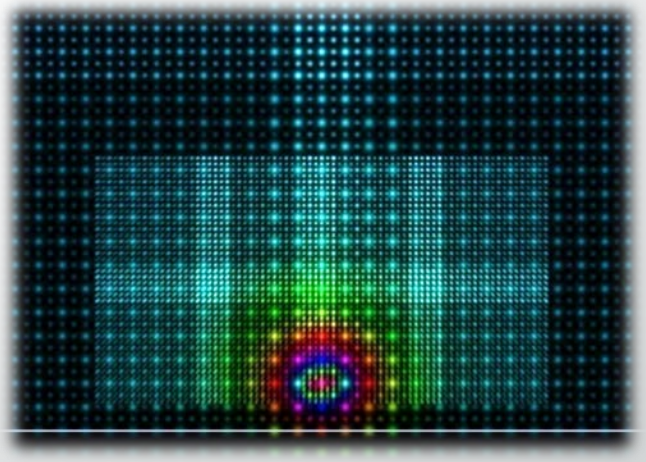
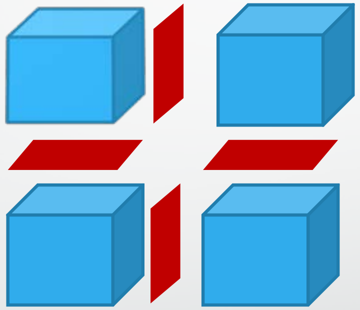
5. (Time) Slice
6. Bundle

Extended Skeletons

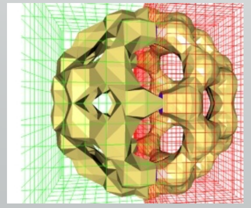
- Refinement Levels - Multiresolution, Adaptive Mesh Refinement

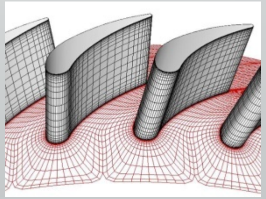


- Cell Complex - Blocks, fragments



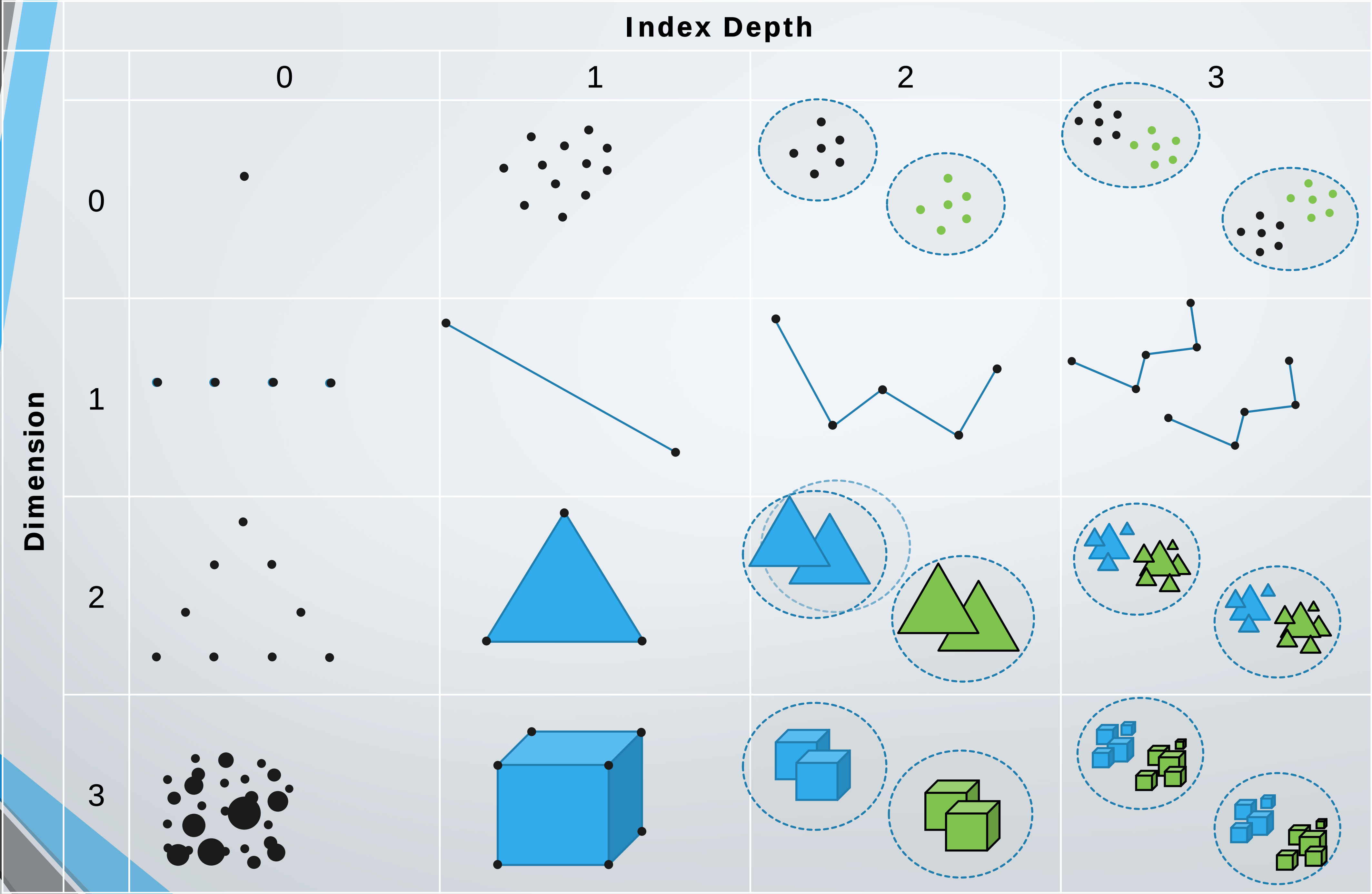
- Topological Relationships
  - Grid future/past
  - Intergrid Relationships



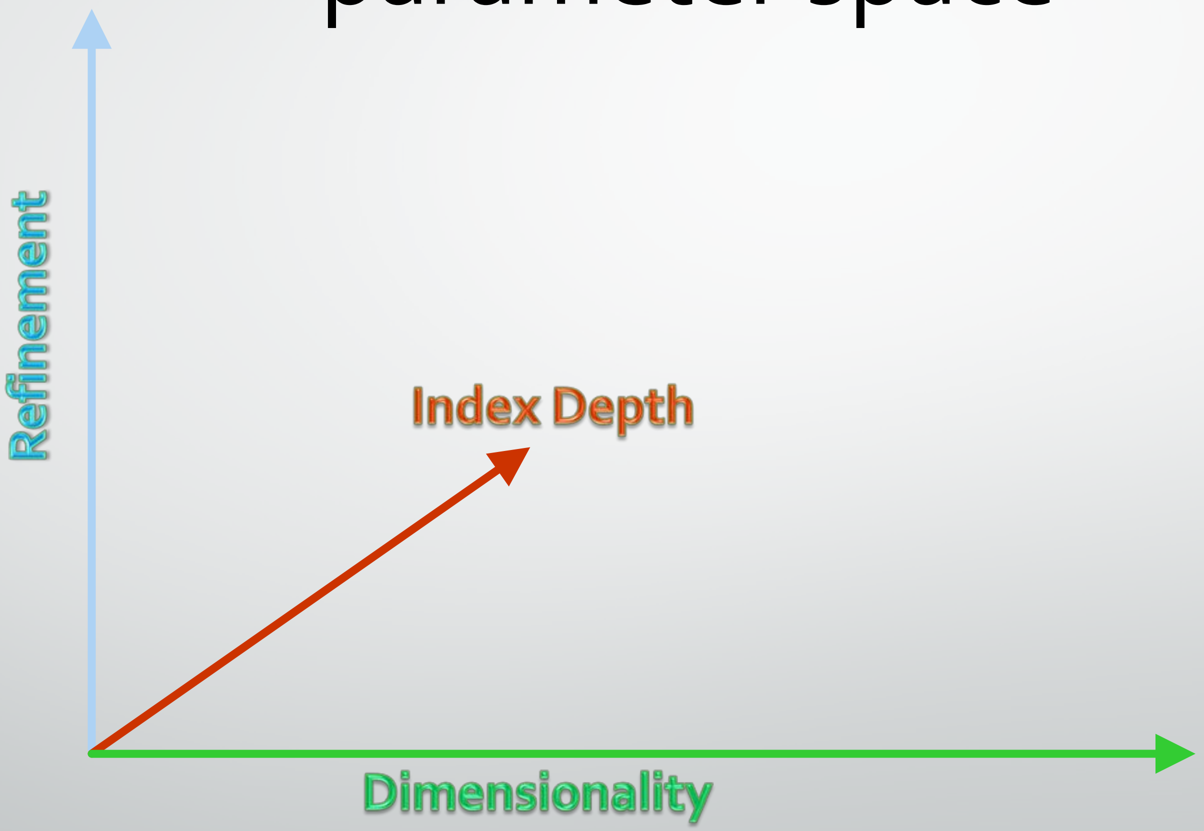


Concept of “Index Depth”

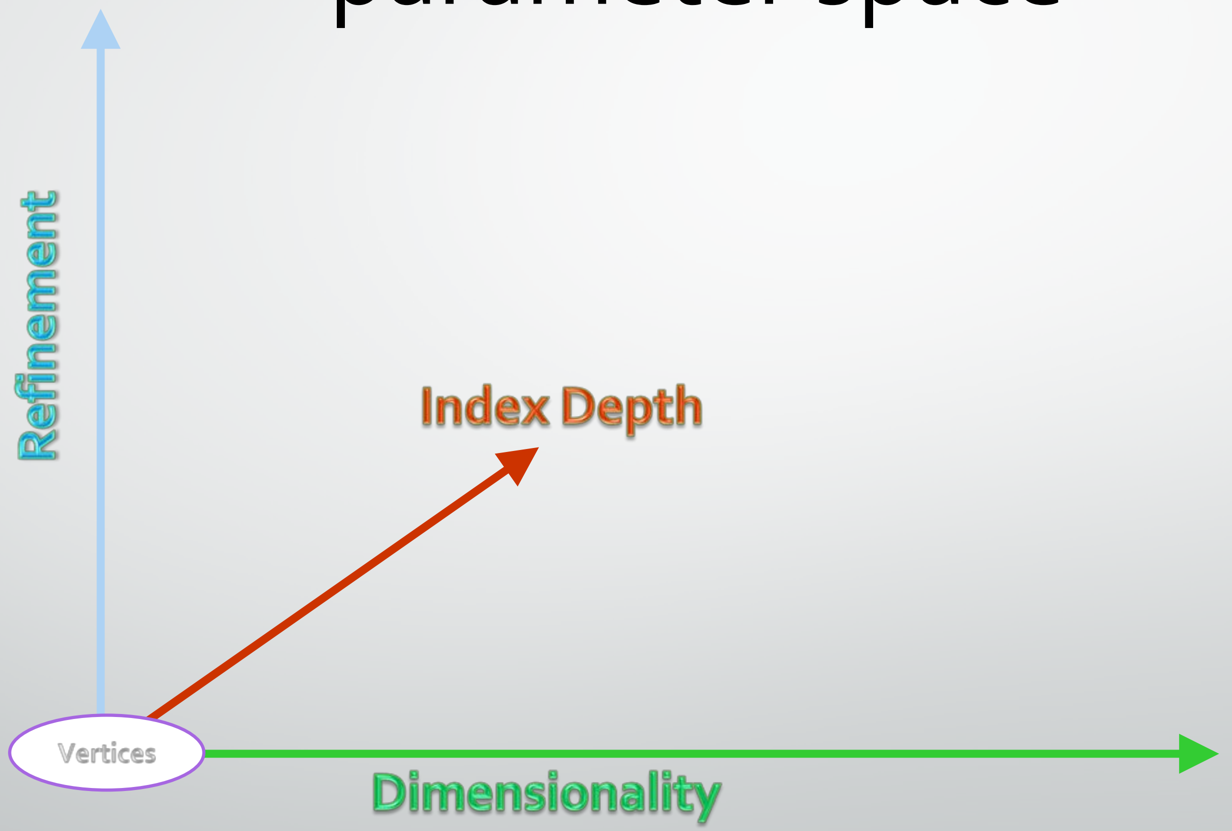
- An integer property of an index space (Skeleton object), similar to dimensionality
  - Dimensionality: intrinsic property
  - Index depth: extrinsic property
- Describes “how far” the index space is from the primary (mandatory) Vertex information of a Grid:
  - 0 → Vertices
  - 1 → Edges, Faces, Tetrahedrons, …
  - 2 → Groups of edges, faces, tetrahedrons
  - 3 → Groups of elements of index depth 2
  - 4 → Groups of 3-elements
  - …


Index Depth
0
1
2
3
Dimension
0
1
2
3

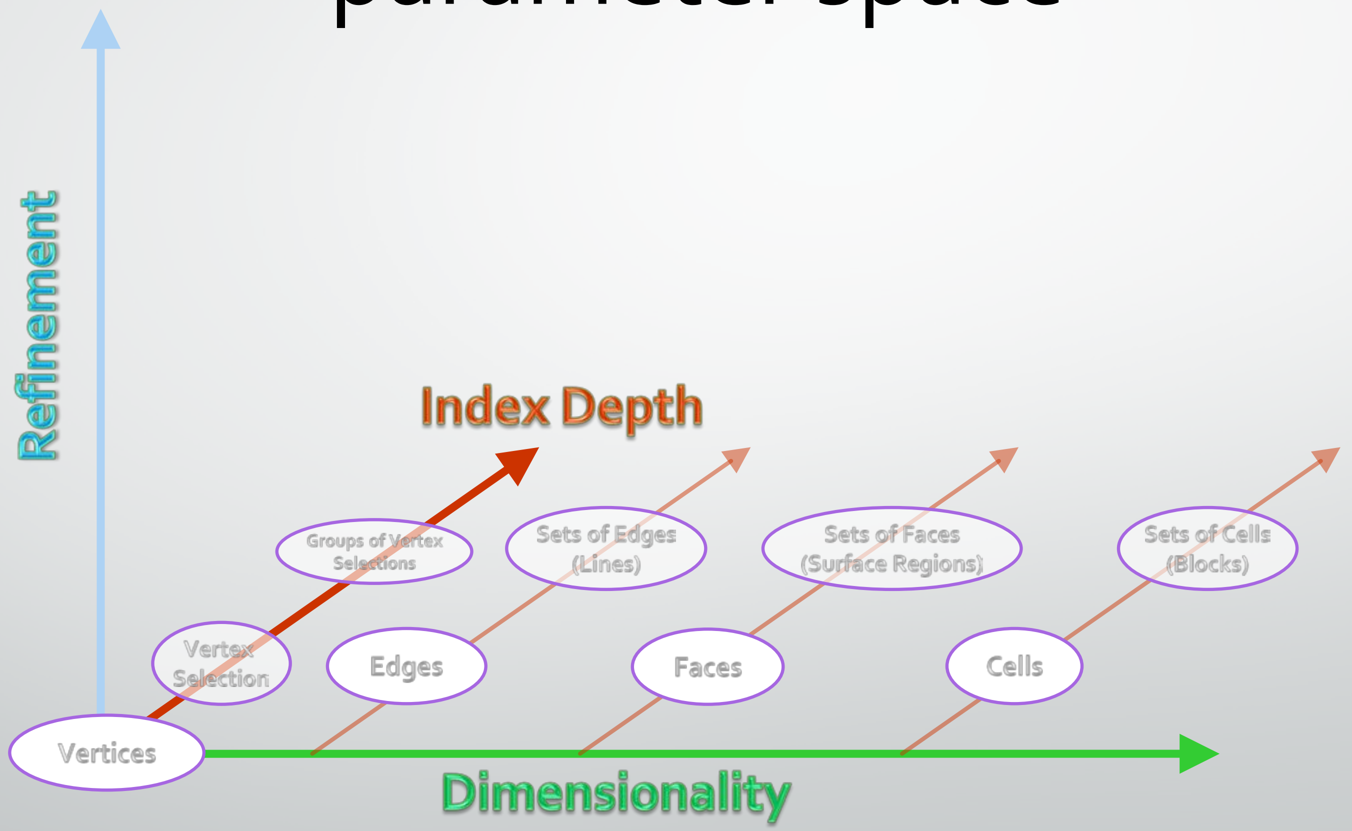
Skeletons as Fibers of a 3-dimensional parameter space



Skeletons as Fibers of a 3-dimensional parameter space

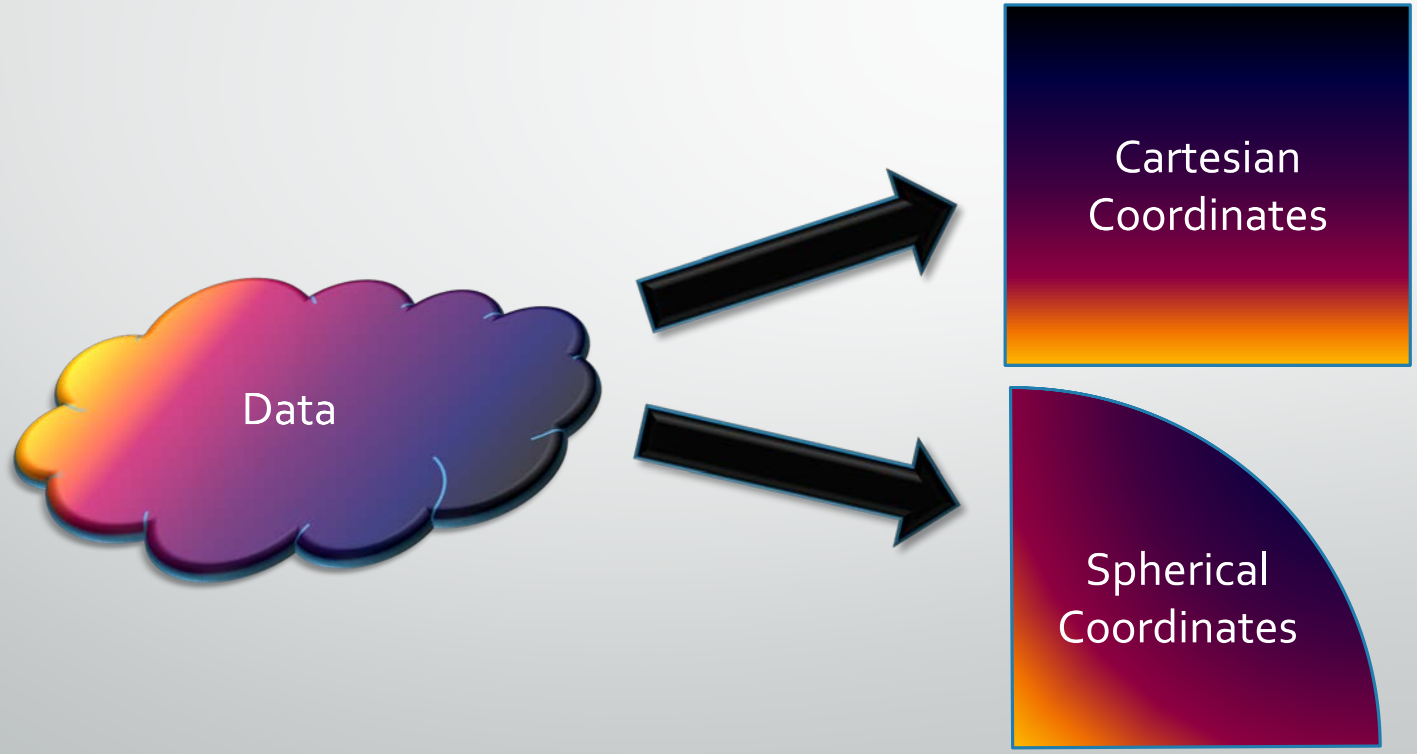


Skeletons as Fibers of a 3-dimensional parameter space

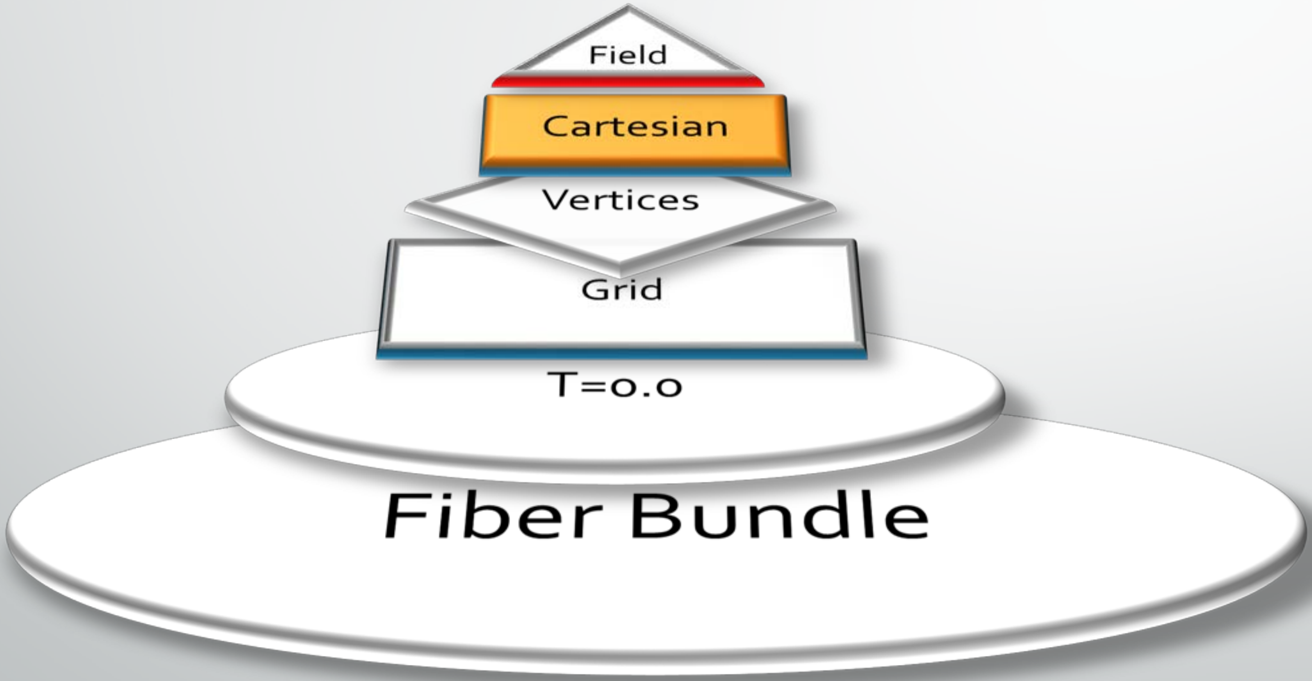


Differential Geometry

Concept of a manifold and charts – numerical data are coordinate-dependent

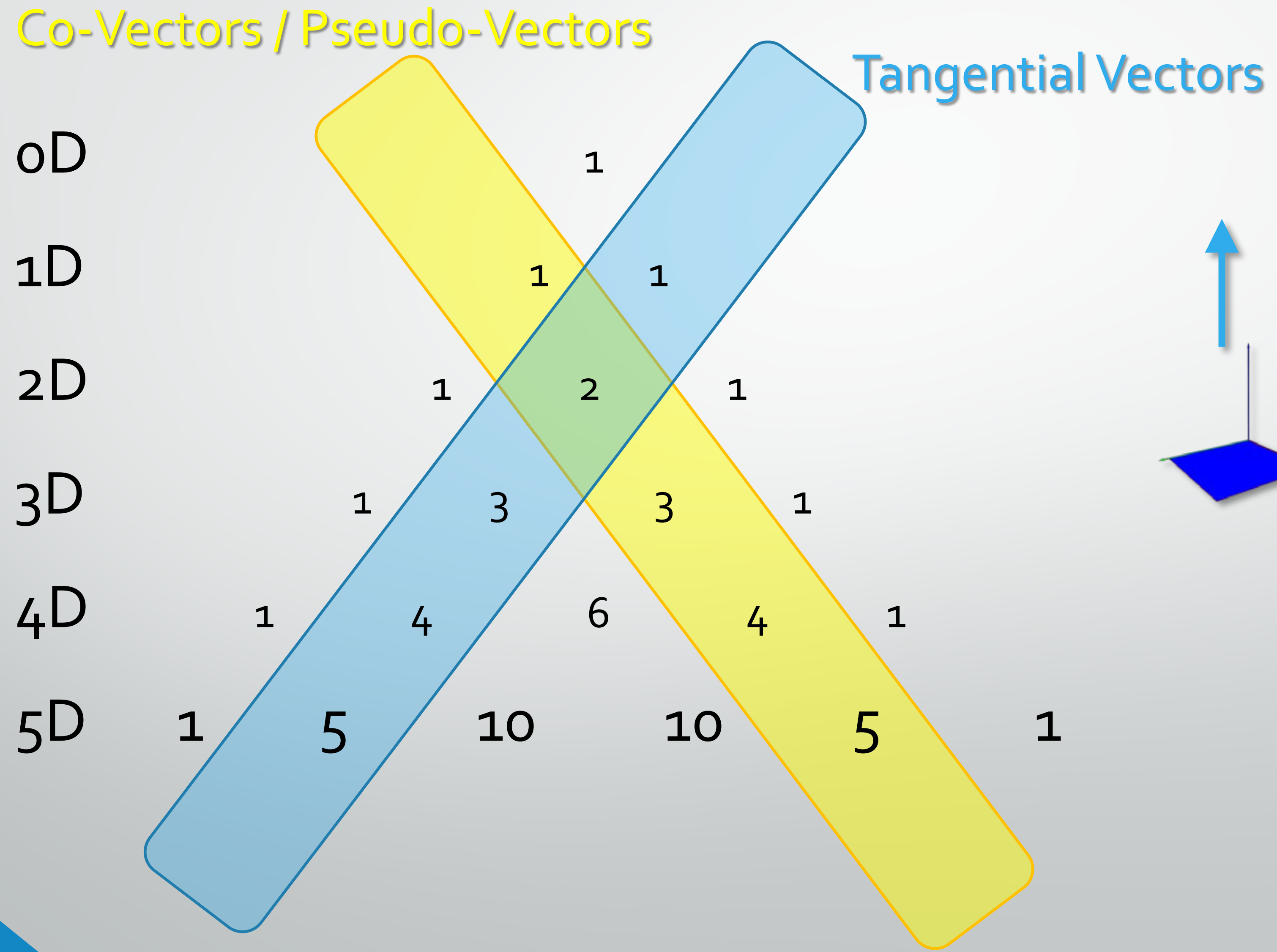


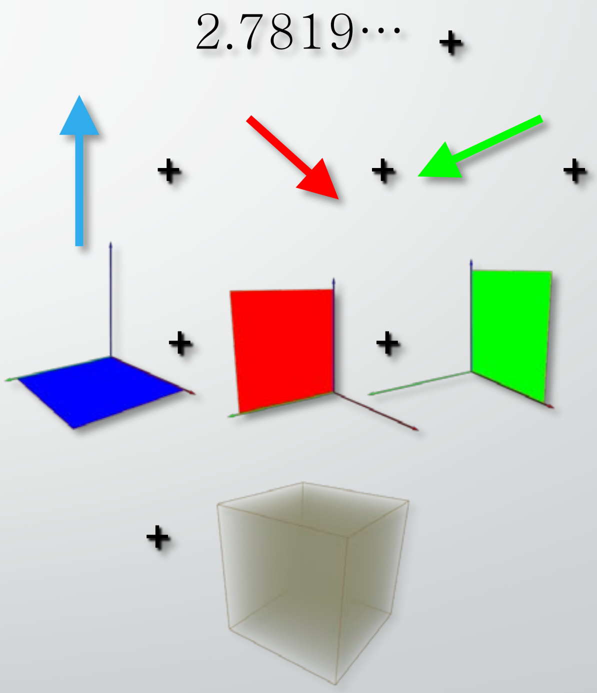
Multiple Representations



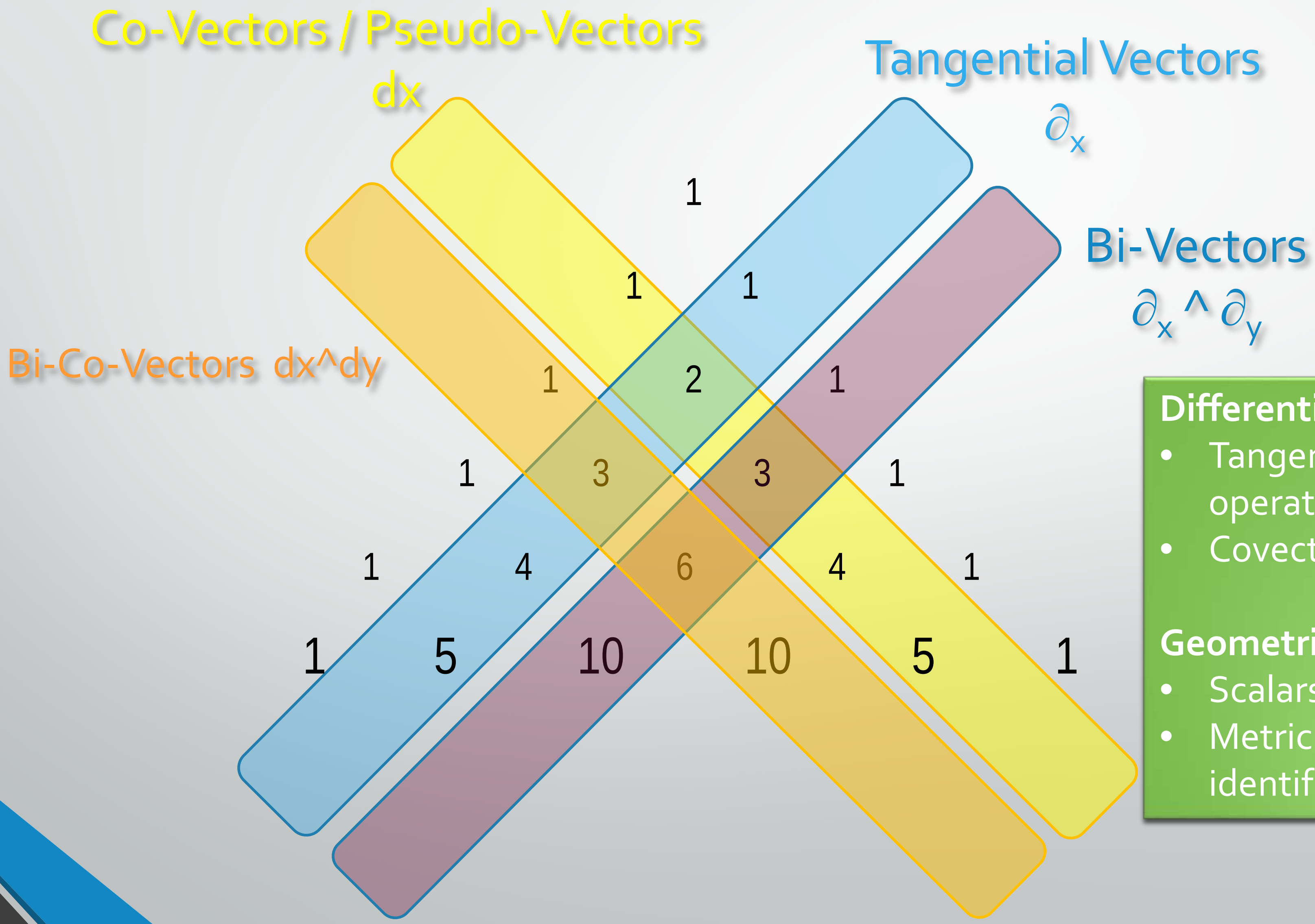
1. Field
2. Representation
3. Skeleton
4. Grid object
5. (Time) Slice
6. Bundle

Tangential / Co- / Bi-Vectors





Co-, Bi-, Pseudo- Vectors



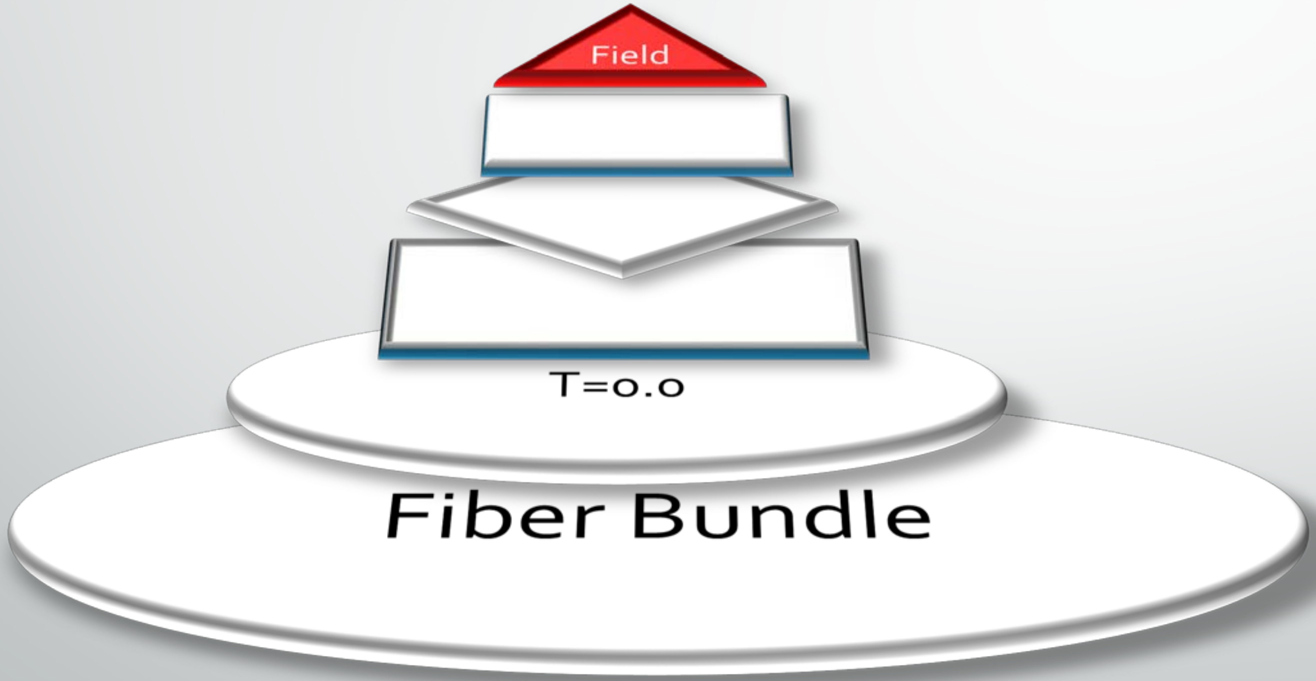
Differential Geometry:

- Tangential vectors as differential operators
- Covectors as integral elements

Geometric Algebra:

- Scalars, Vectors, Bivectors…
- Metric Tensor field allowing identification

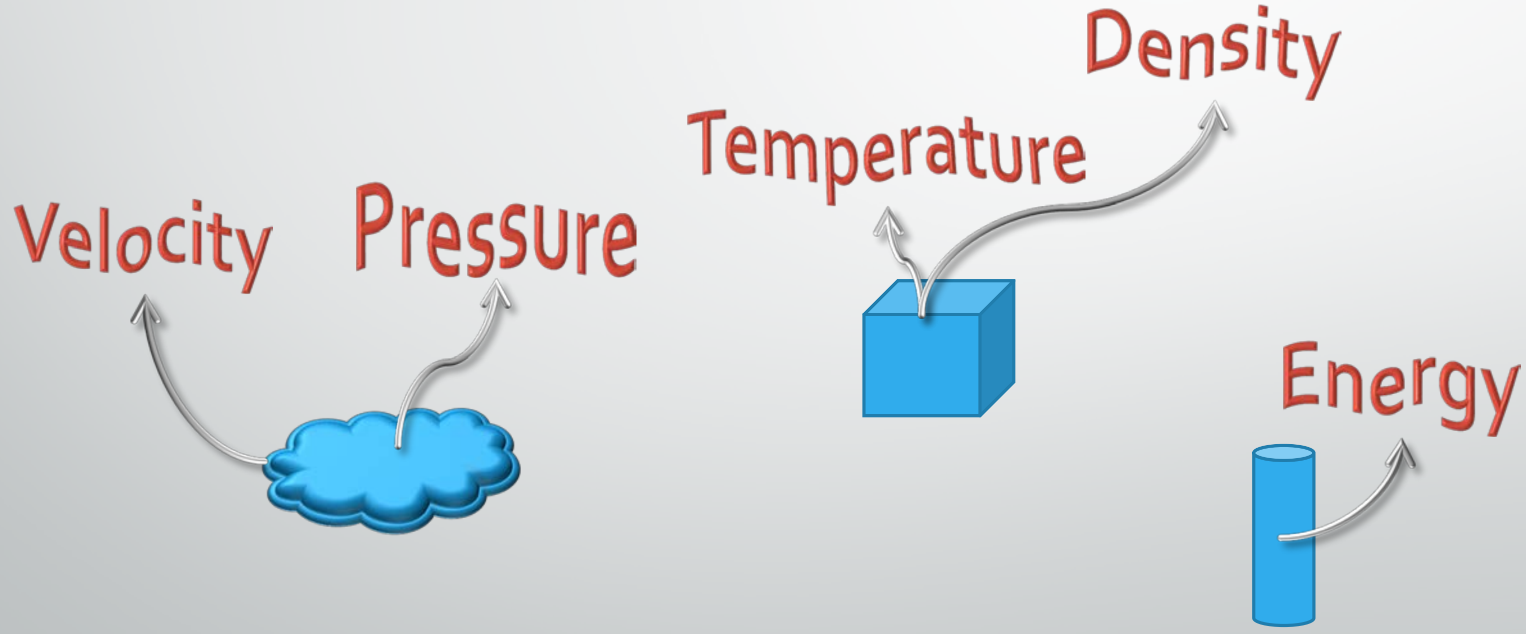
Geometric Algebra: Vectors, Tensors, Spinors, …



1. Field
2. Representation
3. Skeleton
4. Grid object
5. (Time) Slice
6. Bundle

Grids and Fields

End-user operates only on Grid objects and Fields



Practice: The F5 File Format

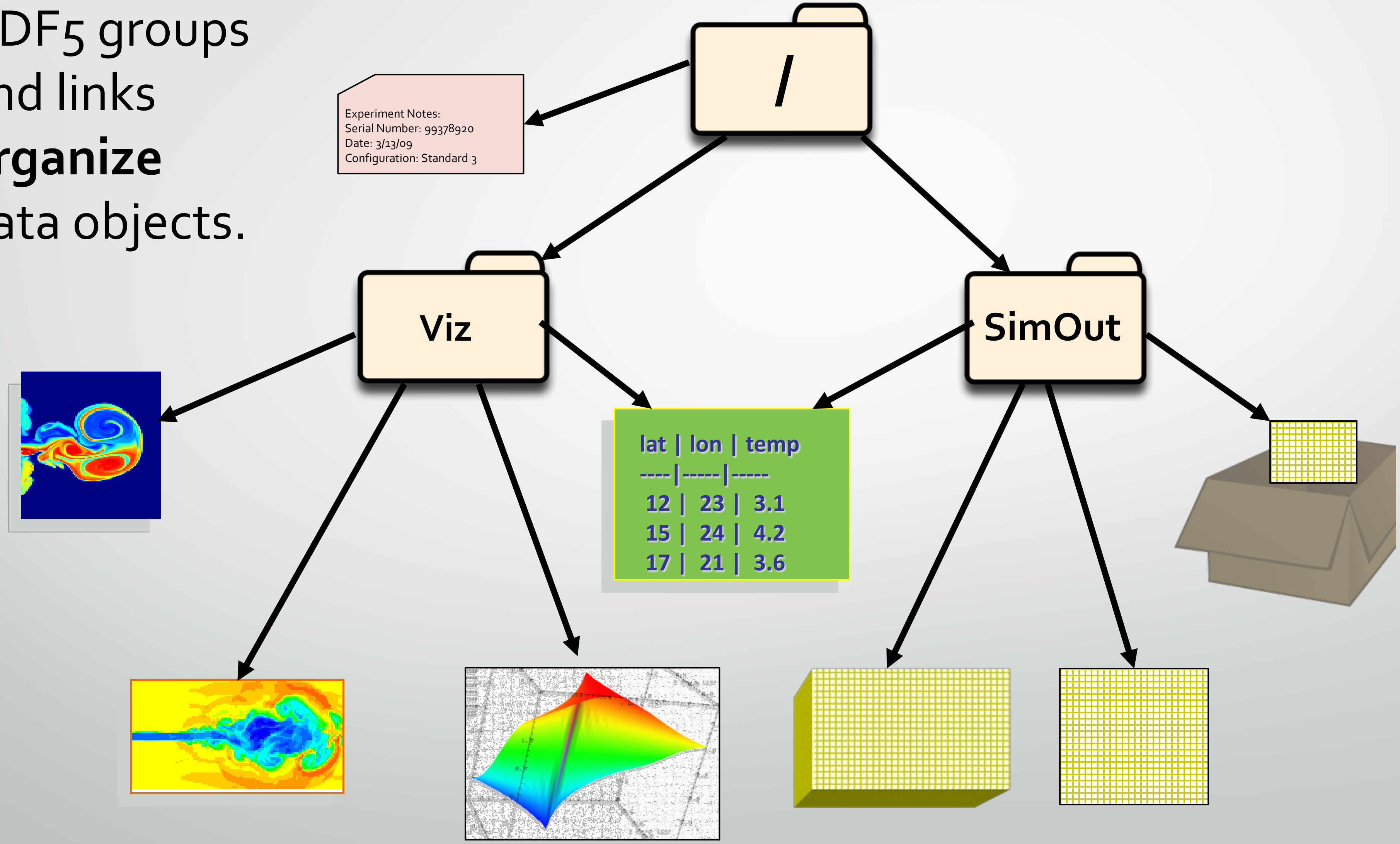
The F5 data model in the Hierarchical Data Format HDF5

HDF = Hierarchical Data Format

- HDF5 is the second HDF format
  - Development started in 1996
  - First release was in 1998
  - http://www.hdfgroup.org
- Designed for HPC simulations
- High-performance, large data, long-term data preservation (archival), portability

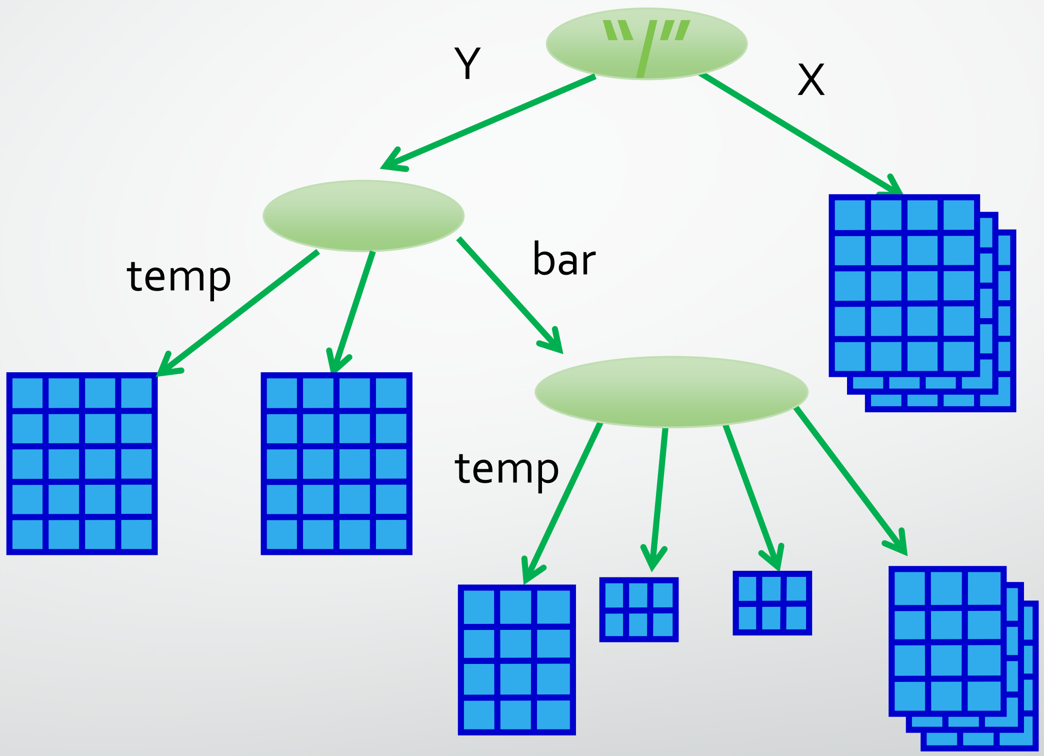
HDF5 Groups and Links

HDF5 groups and links **organize** data objects.



Path to HDF5 object in a file

/ (root)
/X
/Y
/Y/temp
/Y/bar/temp



HDF5 is like a file system in a file, plus with additional meta-information (data type, dimensions, …)

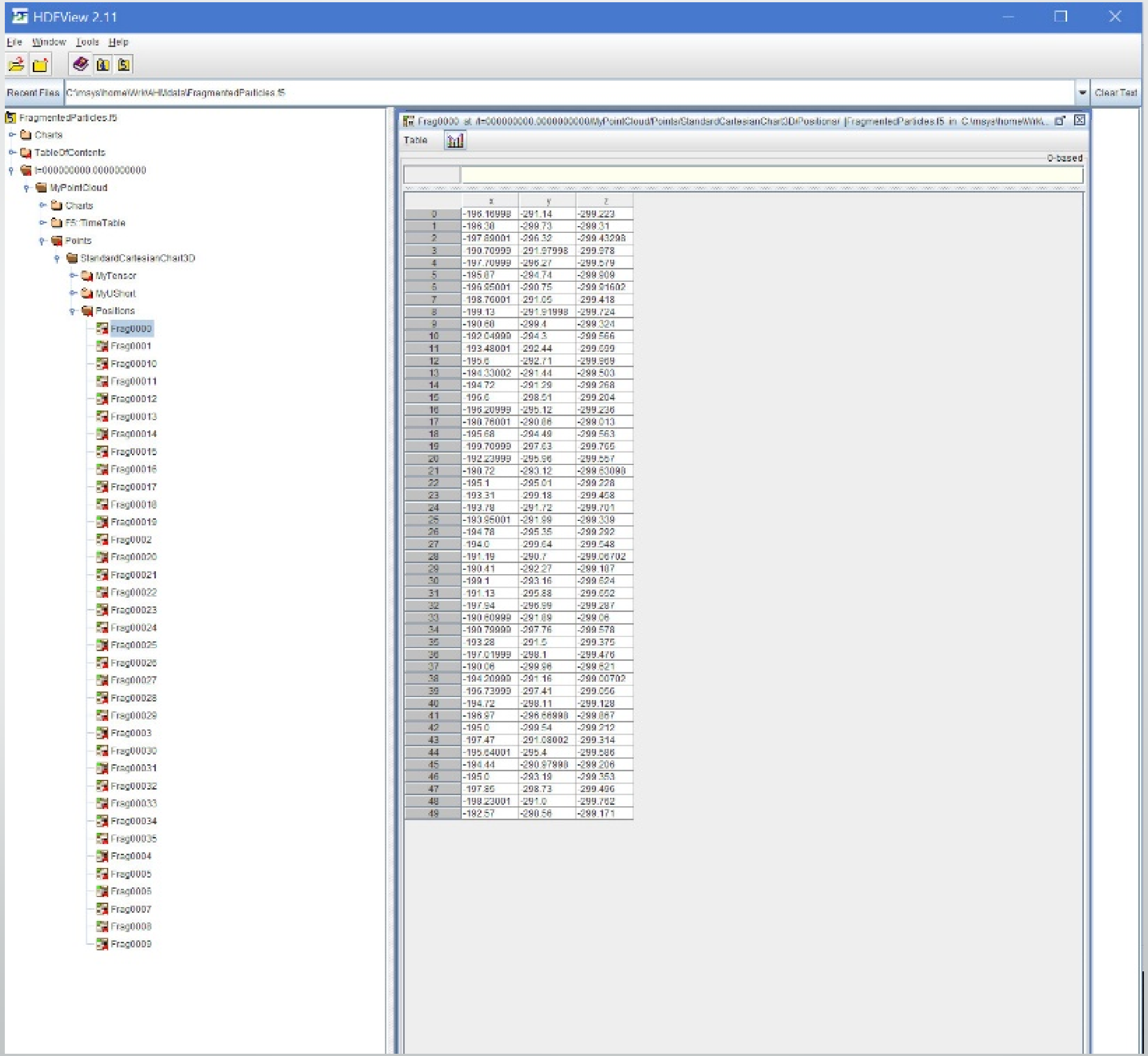
/Time/Grid/Top/Rep/Field/

```
h5ls -r minkowski-0000.f5
/T=0/minkowski/Points/StandardCartesianChart3D Group
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::CURV Group
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::CURV/gxx Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::CURV/gxy Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::CURV/gxz Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::CURV/gyy Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::CURV/gyz Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::CURV/gzz Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::LAPSE Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::METRIC Group
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::METRIC/gxx Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::METRIC/gxy Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::METRIC/gxz Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::METRIC/gyy Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::METRIC/gyz Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/ADMBASE::METRIC/gzz Dataset {43, 37, 19}
/T=0/minkowski/Points/StandardCartesianChart3D/Positions Group
/T=0.119047619047619041010577234374 Group
/T=0.119047619047619041010577234374/minkowski Group
```

HDFView
Browsing HDF5 Files

Fragmented Particles

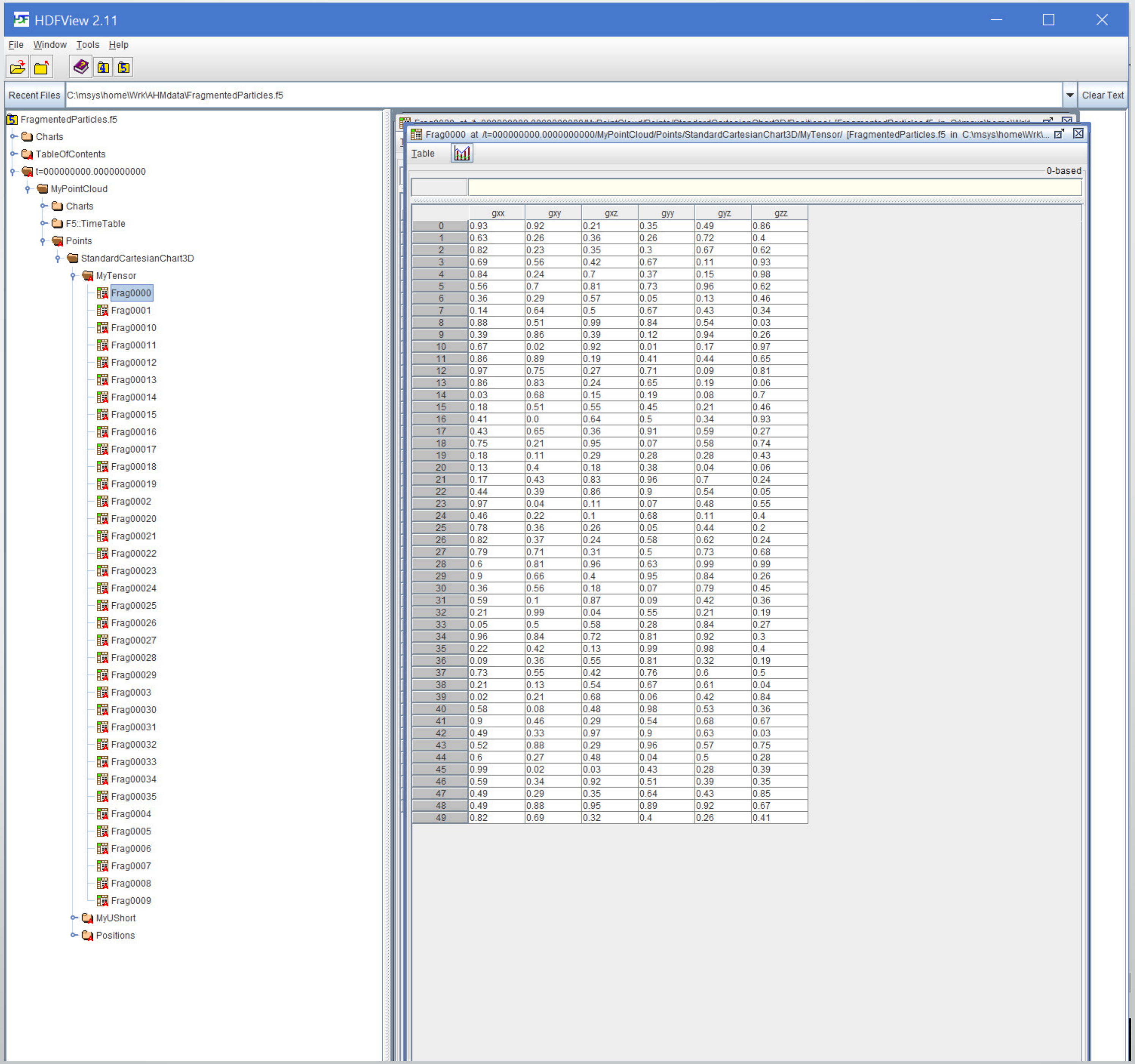
Coordinates



HDFView
Browsing HDF5 Files

Fragmented Particles

A Tensor Field
(six components)



	gxx	gxy	gxz	gyy	gyz	gzz
0	0.93	0.92	0.21	0.35	0.49	0.86
1	0.63	0.26	0.36	0.26	0.72	0.4
2	0.82	0.23	0.35	0.3	0.67	0.62
3	0.69	0.56	0.42	0.67	0.11	0.93
4	0.84	0.24	0.7	0.37	0.15	0.98
5	0.56	0.7	0.81	0.73	0.96	0.62
6	0.36	0.29	0.57	0.05	0.13	0.46
7	0.14	0.64	0.5	0.67	0.43	0.34
8	0.88	0.51	0.99	0.84	0.54	0.03
9	0.39	0.86	0.39	0.12	0.94	0.26
10	0.67	0.02	0.92	0.01	0.17	0.97
11	0.86	0.89	0.19	0.41	0.44	0.65
12	0.97	0.75	0.27	0.71	0.09	0.81
13	0.86	0.83	0.24	0.65	0.19	0.06
14	0.03	0.68	0.15	0.19	0.08	0.7
15	0.18	0.51	0.55	0.45	0.21	0.46
16	0.41	0.0	0.64	0.5	0.34	0.93
17	0.43	0.65	0.36	0.91	0.59	0.27
18	0.75	0.21	0.95	0.07	0.58	0.74
19	0.18	0.11	0.29	0.28	0.28	0.43
20	0.13	0.4	0.18	0.38	0.04	0.06
21	0.17	0.43	0.83	0.96	0.7	0.24
22	0.44	0.39	0.86	0.9	0.54	0.05
23	0.97	0.04	0.11	0.07	0.48	0.55
24	0.46	0.22	0.1	0.68	0.11	0.4
25	0.78	0.36	0.26	0.05	0.44	0.2
26	0.82	0.37	0.24	0.58	0.62	0.24
27	0.79	0.71	0.31	0.5	0.73	0.68
28	0.6	0.81	0.96	0.63	0.99	0.99
29	0.9	0.66	0.4	0.95	0.84	0.26
30	0.36	0.56	0.18	0.07	0.79	0.45
31	0.59	0.1	0.87	0.09	0.42	0.36
32	0.21	0.99	0.04	0.55	0.21	0.19
33	0.05	0.5	0.58	0.28	0.84	0.27
34	0.96	0.84	0.72	0.81	0.92	0.3
35	0.22	0.42	0.13	0.99	0.98	0.4
36	0.09	0.36	0.55	0.81	0.32	0.19
37	0.73	0.55	0.42	0.76	0.6	0.5
38	0.21	0.13	0.54	0.67	0.61	0.04
39	0.02	0.21	0.68	0.06	0.42	0.84
40	0.58	0.08	0.48	0.98	0.53	0.36
41	0.9	0.46	0.29	0.54	0.68	0.67
42	0.49	0.33	0.97	0.9	0.63	0.03
43	0.52	0.88	0.29	0.96	0.57	0.75
44	0.6	0.27	0.48	0.04	0.5	0.28
45	0.99	0.02	0.03	0.43	0.28	0.39
46	0.59	0.34	0.92	0.51	0.39	0.35
47	0.49	0.29	0.35	0.64	0.43	0.85
48	0.49	0.88	0.95	0.89	0.92	0.67
49	0.82	0.69	0.32	0.4	0.26	0.41

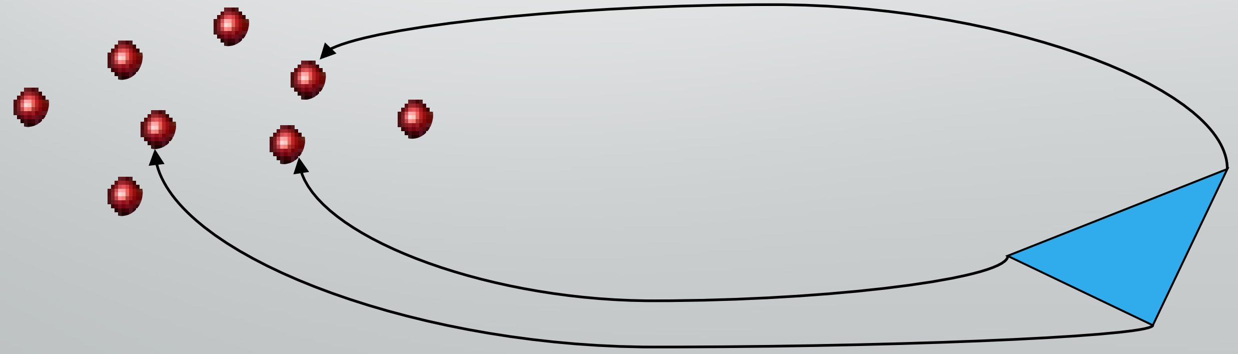
Relative Representations

Triangular Surface: 600331 Triangles, 314442 Points

```
/T=1                        Group
/T=1/adcirc                 Group
/T=1/adcirc/Points          Group
/T=1/adcirc/Points/StandardCartesianChart3D Group
/T=1/adcirc/Points/StandardCartesianChart3D/Positions Dataset {314442}
/T=1/adcirc/Connectivity Group
/T=1/adcirc/Connectivity/Points Group
/T=1/adcirc/Connectivity/Points/Positions Dataset {600331}
```

Index Depth = 0

Index Depth = 1

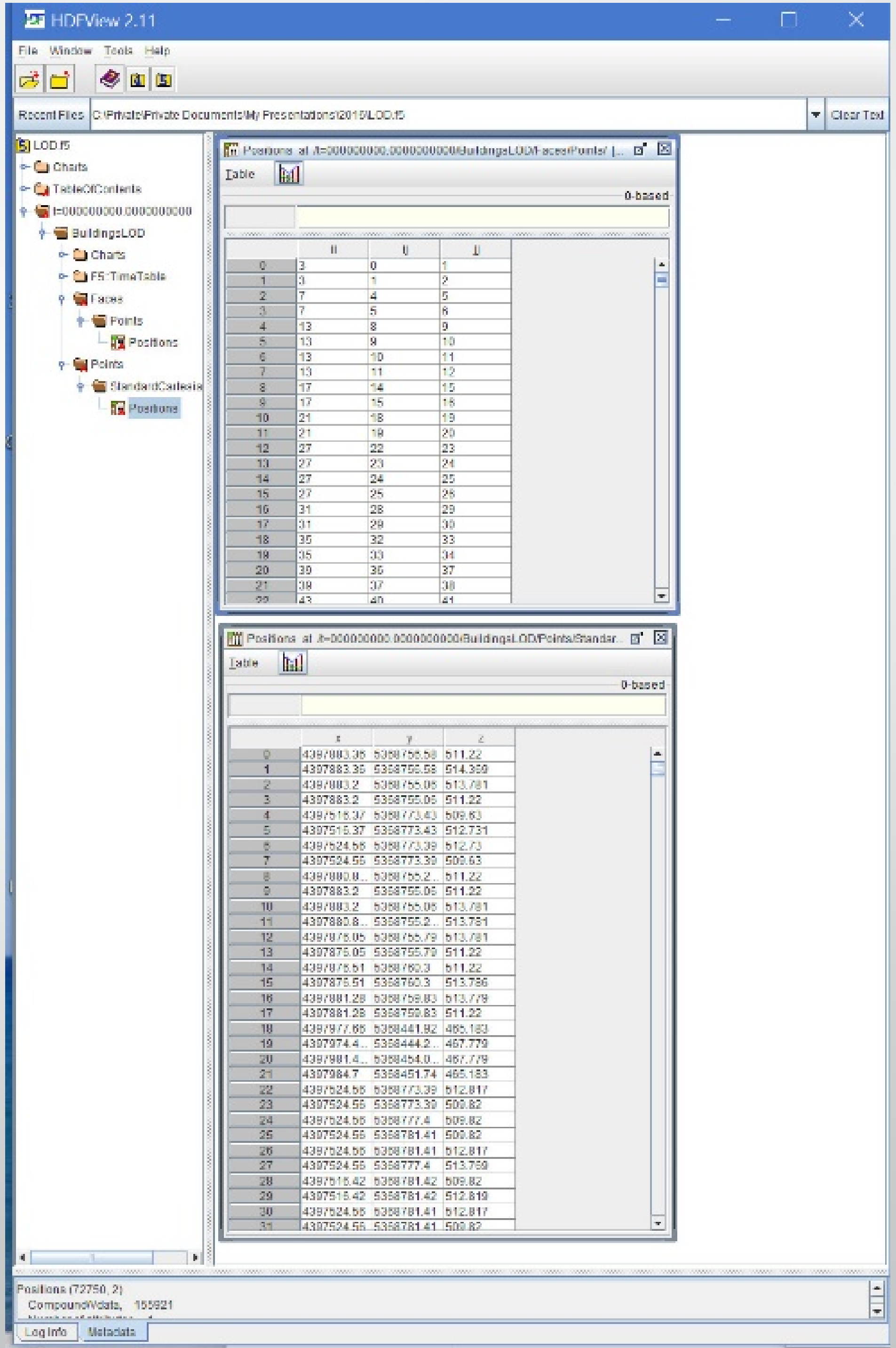


HDFView Browsing HDF5 Files

Triangular Surface

- Coordinates
- Triangle Indices

LOD.f5

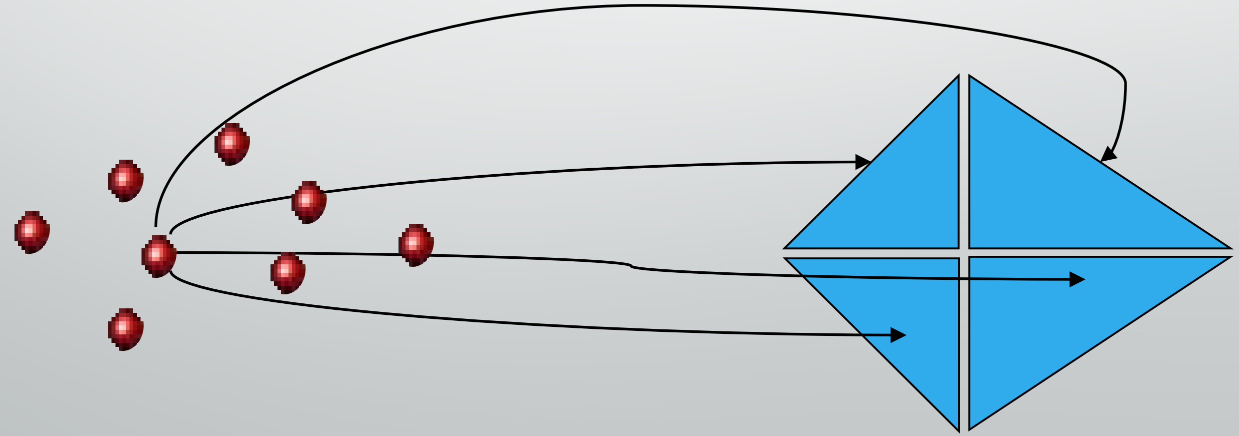


Relative Representations

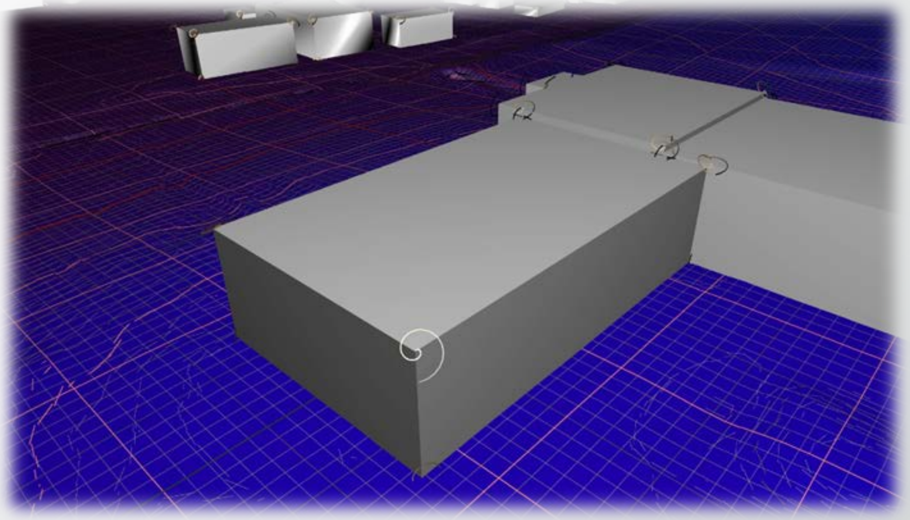
Inverse Information: Triangles per Vertex

```
/T=1                         Group
/T=1/adcirc                  Group
/T=1/adcirc/Points           Group
/T=1/adcirc/Points/StandardCartesianChart3D Group
/T=1/adcirc/Points/StandardCartesianChart3D/Positions Dataset {314442}
/T=1/adcirc/Points/Connectivity/Positions Dataset {314442}

/T=1/adcirc/Connectivity Group
/T=1/adcirc/Connectivity/Points Group
/T=1/adcirc/Connectivity/Points/Positions Dataset {600331}
```



Fields on Relative Representations

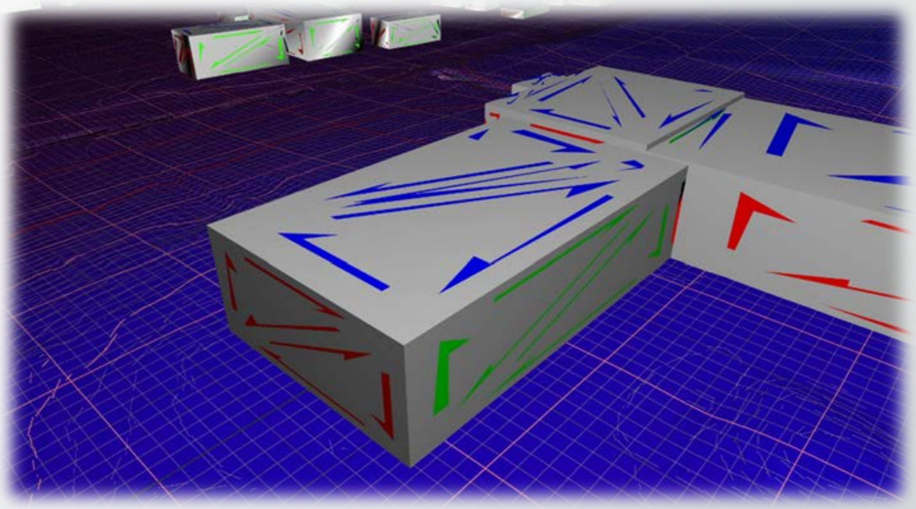


Triangular Surface: 600331 Triangles, 414442 Points

plus data on the vertices

```
/T=1                        Group
/T=1/adcirc/Connectivity Group
/T=1/adcirc/Connectivity/Points Group
/T=1/adcirc/Connectivity/Points/Positions Dataset {600331}
/T=1/adcirc/Points          Group
/T=1/adcirc/Points/StandardCartesianChart3D Group
/T=1/adcirc/Points/StandardCartesianChart3D/Positions Dataset {314442}
/T=1/adcirc/Points/StandardCartesianChart3D/elevation Dataset {314442}
/T=1/adcirc/Points/StandardCartesianChart3D/vector Dataset {314442}
```

Fields on Relative Representations

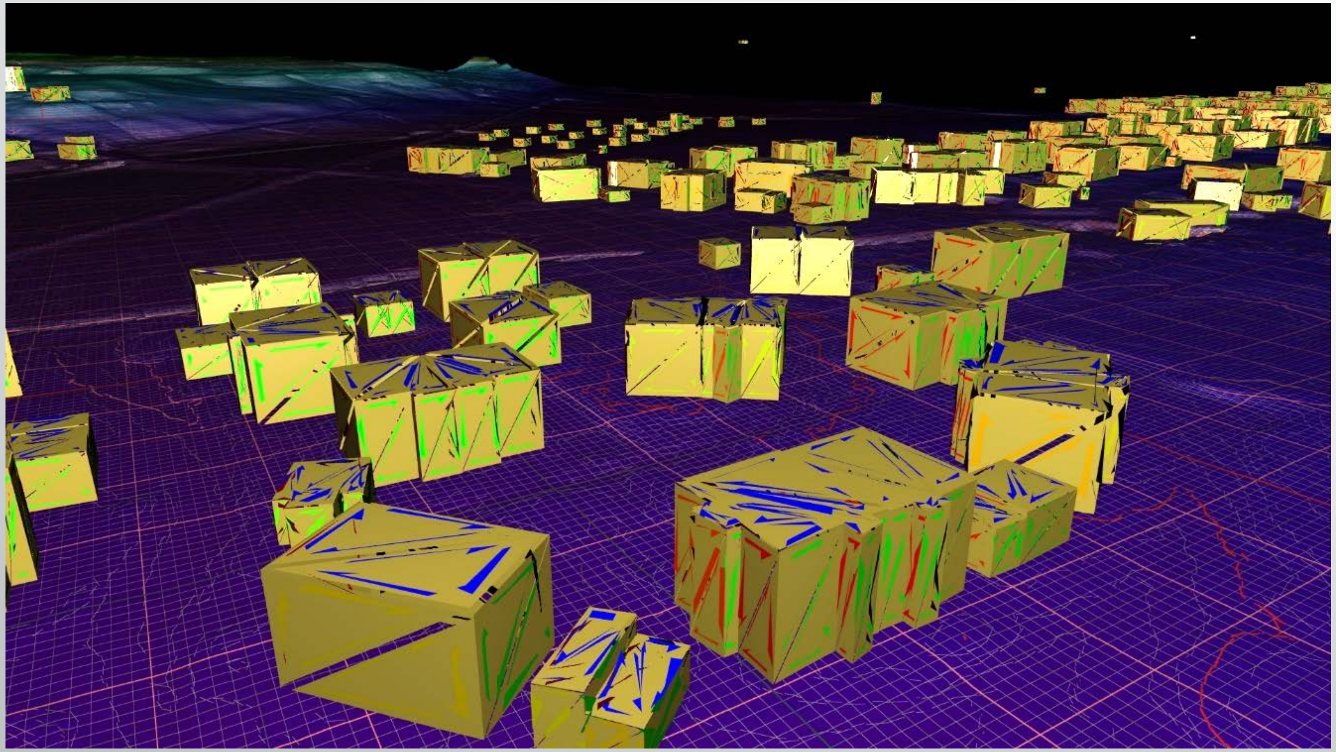


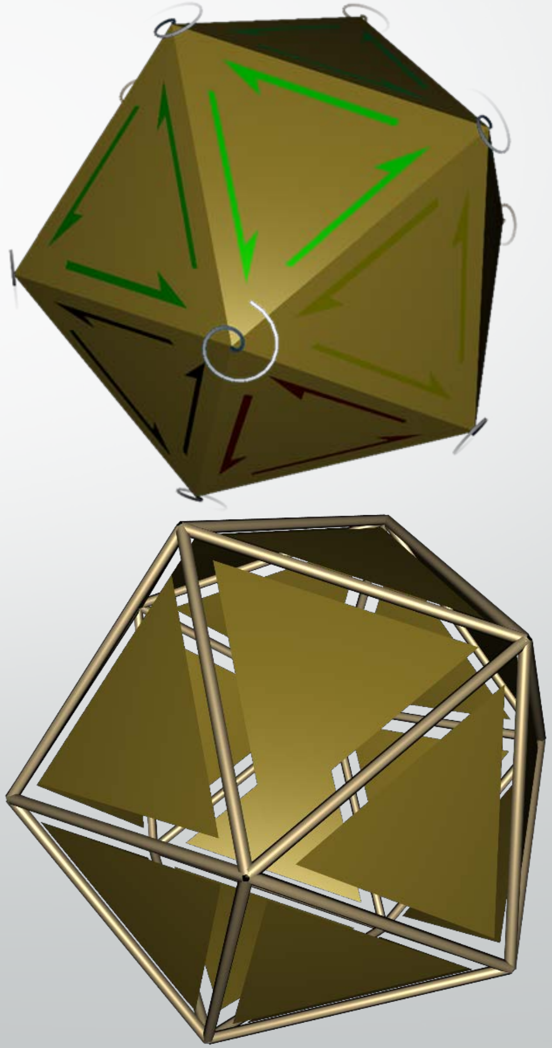
Triangular Surface: 600331 Triangles, 414442 Points

plus data on the triangles

```
/T=1                         Group
/T=1/adcirc/Connectivity Group
/T=1/adcirc/Connectivity/Points Group
/T=1/adcirc/Connectivity/Points/Positions Dataset {600331}
/T=1/adcirc/Connectivity/StandardCartesianChart3D/elevation Dataset {600331}
/T=1/adcirc/Connectivity/StandardCartesianChart3D/vector Dataset {600331}
/T=1/adcirc/Points       Group
/T=1/adcirc/Points/StandardCartesianChart3D Group
/T=1/adcirc/Points/StandardCartesianChart3D/Positions Dataset {314442}
```

Data Fields on topological Skeletons
Vertices, Edges, Faces, Sets of Edges…





Unstructured Meshes

Skeletons and Primary Representations

Index Depth 0

```
/T=1                      Group
/T=1/adcirc               Group
/T=1/adcirc/Points        Group
/T=1/adcirc/Points/StandardCartesianChart3D Group
/T=1/adcirc/Points/StandardCartesianChart3D/Positions Dataset
```

Index Depth = 1

```
/T=1/adcirc/Edges Group
/T=1/adcirc/Edges/Points Group
/T=1/adcirc/Edges/Points/Positions Dataset
```

Dimensionality 1

```
/T=1/adcirc/Faces Group
/T=1/adcirc/Faces/Points Group
/T=1/adcirc/Faces/Points/Positions Dataset
```

Dimensionality 2

```
/T=1/adcirc/Connectivity Group
/T=1/adcirc/Connectivity/Points Group
/T=1/adcirc/Connectivity/Points/Positions Dataset
```

Dimensionality 3

Unstructured Meshes

Skeletons and Secondary Representations

```
/T=1                          Group
/T=1/adcirc                   Group
/T=1/adcirc/Points            Group
/T=1/adcirc/Points/StandardCartesianChart3D Group
/T=1/adcirc/Points/StandardCartesianChart3D/Positions Dataset
/T=1/adcirc/Points/Faces Group
/T=1/adcirc/Points/Faces/Positions Dataset

/T=1/adcirc/Edges Group
/T=1/adcirc/Edges/Faces Group
/T=1/adcirc/Edges/Faces/Positions Dataset

/T=1/adcirc/Faces Group
/T=1/adcirc/Faces/Edges Group
/T=1/adcirc/Faces/Edges/Positions Dataset

/T=1/adcirc/Connectivity Group
/T=1/adcirc/Connectivity/Edges Group
/T=1/adcirc/Connectivity/Edges/Positions Dataset
```

Faces per Vertex

Faces per Edge

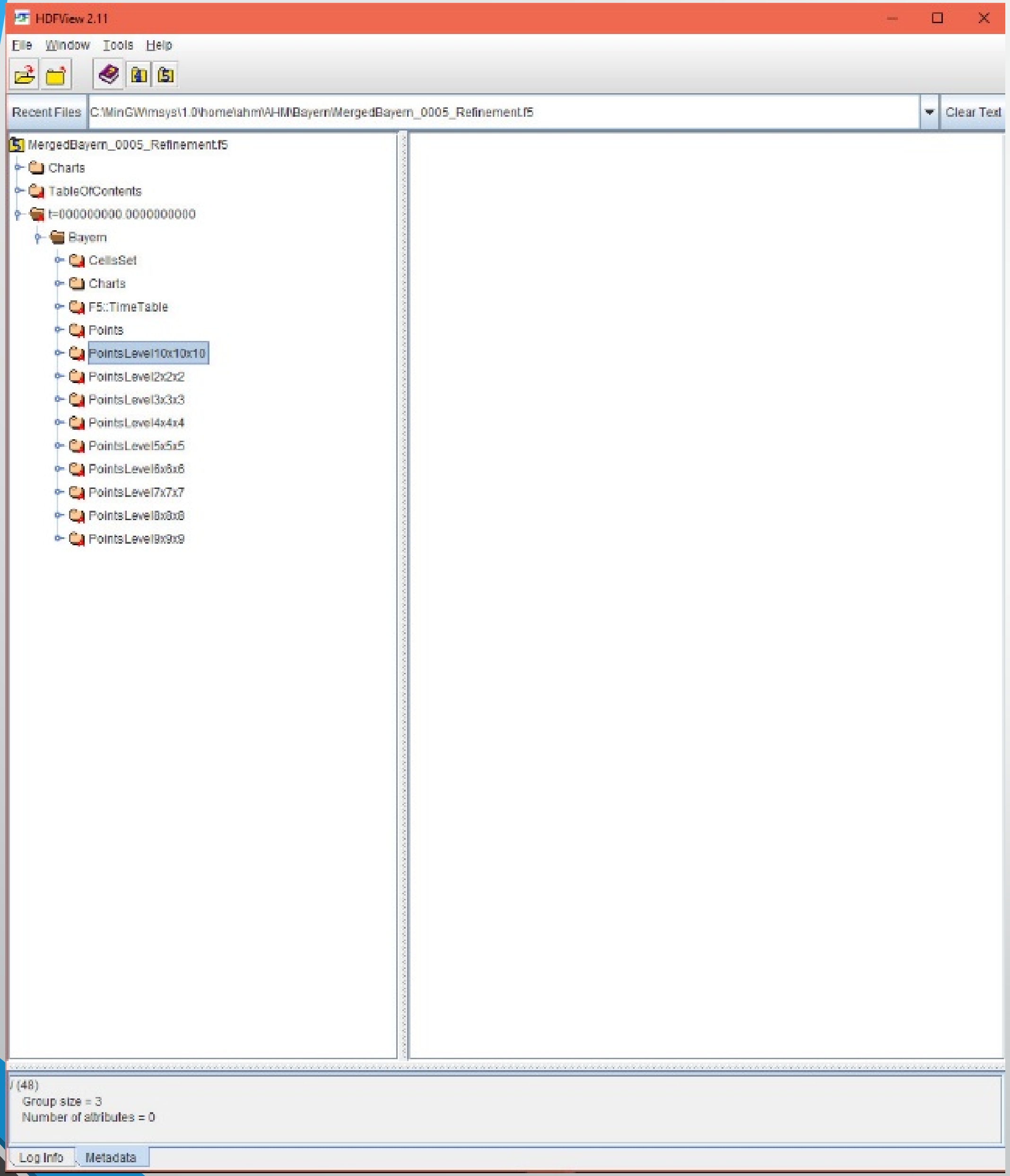
Edges per Face

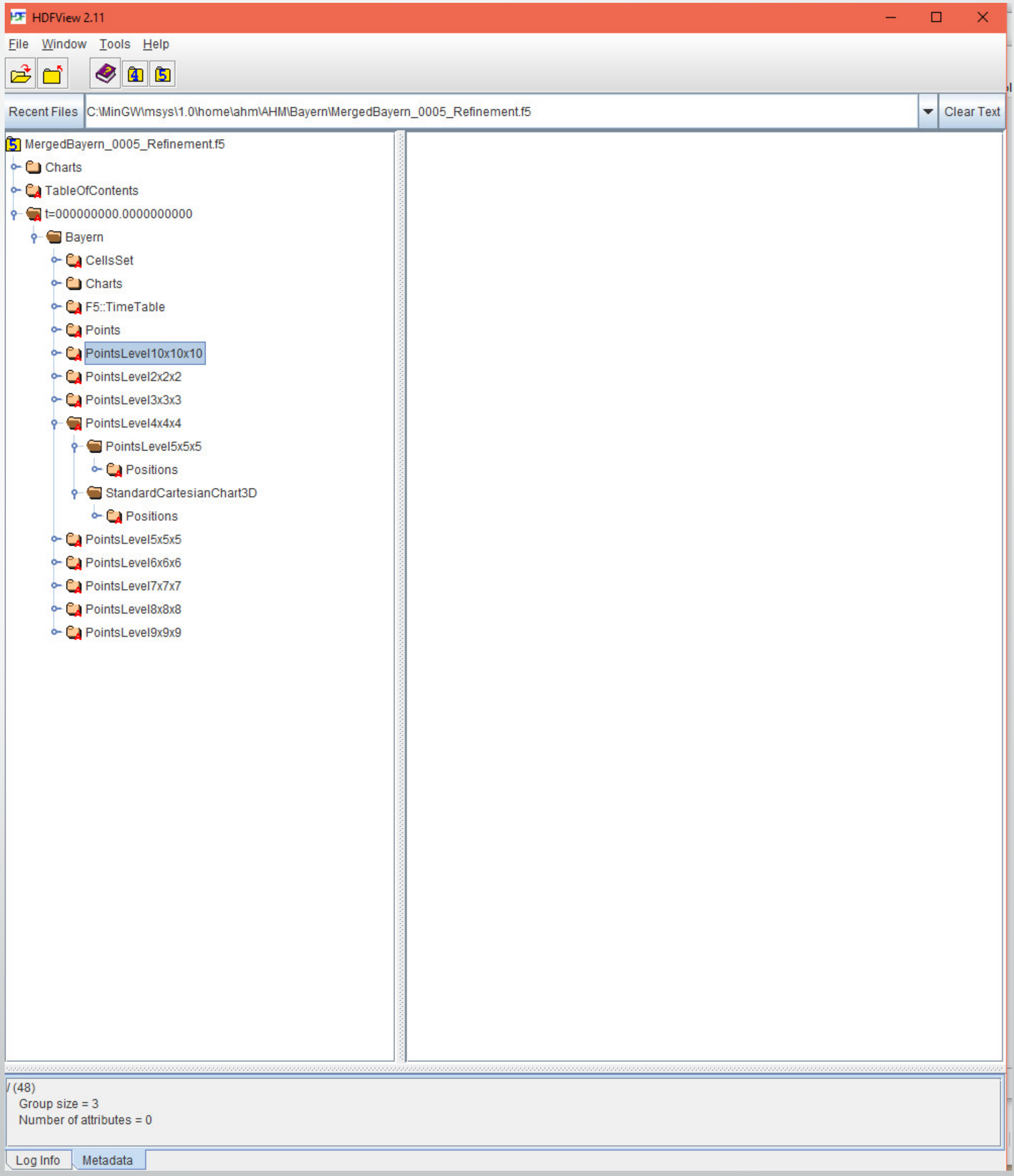
Edges per Cell

Hierarchical Skeletons

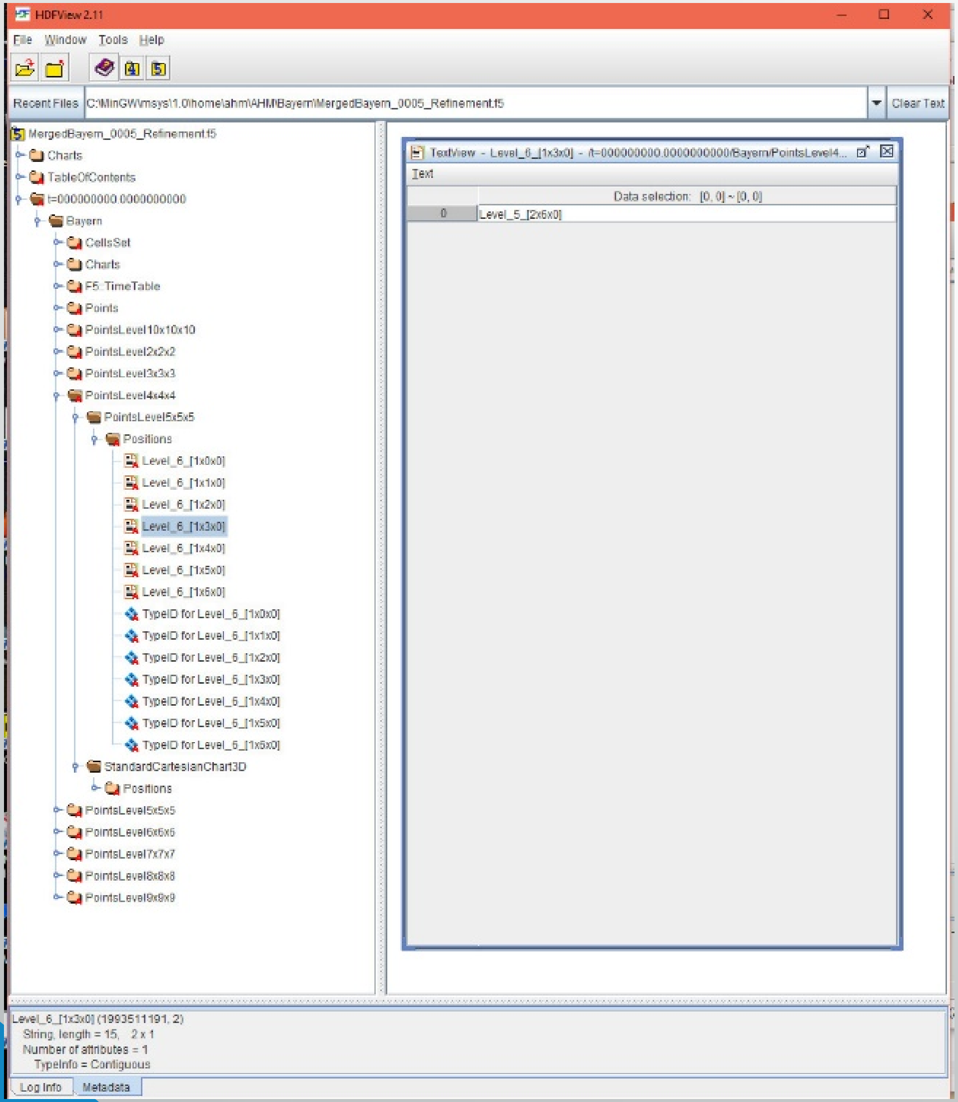
- Third identification parameter on Skeletons:

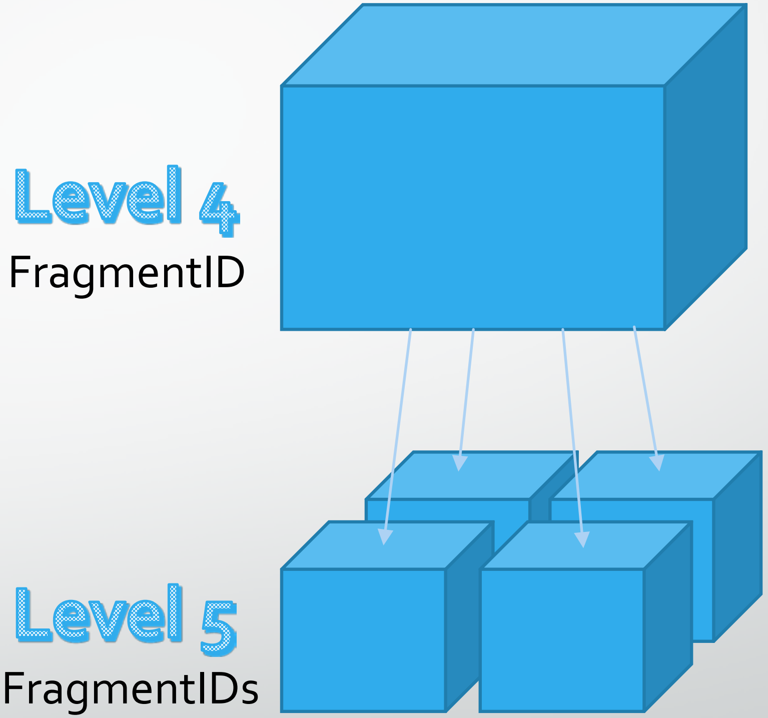
  “refinement” (integer valued or n-dimensional set of integer valued group attribute)
- Allows to formulate “a grid within a grid”
- Replicates topological structure on different refinement levels


HDFView 2.11
File Window Tools Help
Recent Files C:\MinGW\msys\1.0\home\ahm\AHM\Bayern\MergedBayern_0005_Refinement.f5
Clear Text
MergedBayern_0005_Refinement.f5
Charts
TableOfContents
t=000000000.0000000000
Bayern
CellsSet
Charts
F5::TimeTable
Points
PointsLevel10x10x10
PointsLevel2x2x2
PointsLevel3x3x3
PointsLevel4x4x4
PointsLevel5x5x5
PointsLevel6x6x6
PointsLevel7x7x7
PointsLevel8x8x8
PointsLevel9x9x9
/ (48)
Group size = 3
Number of attributes = 0
Log Info
Metadata

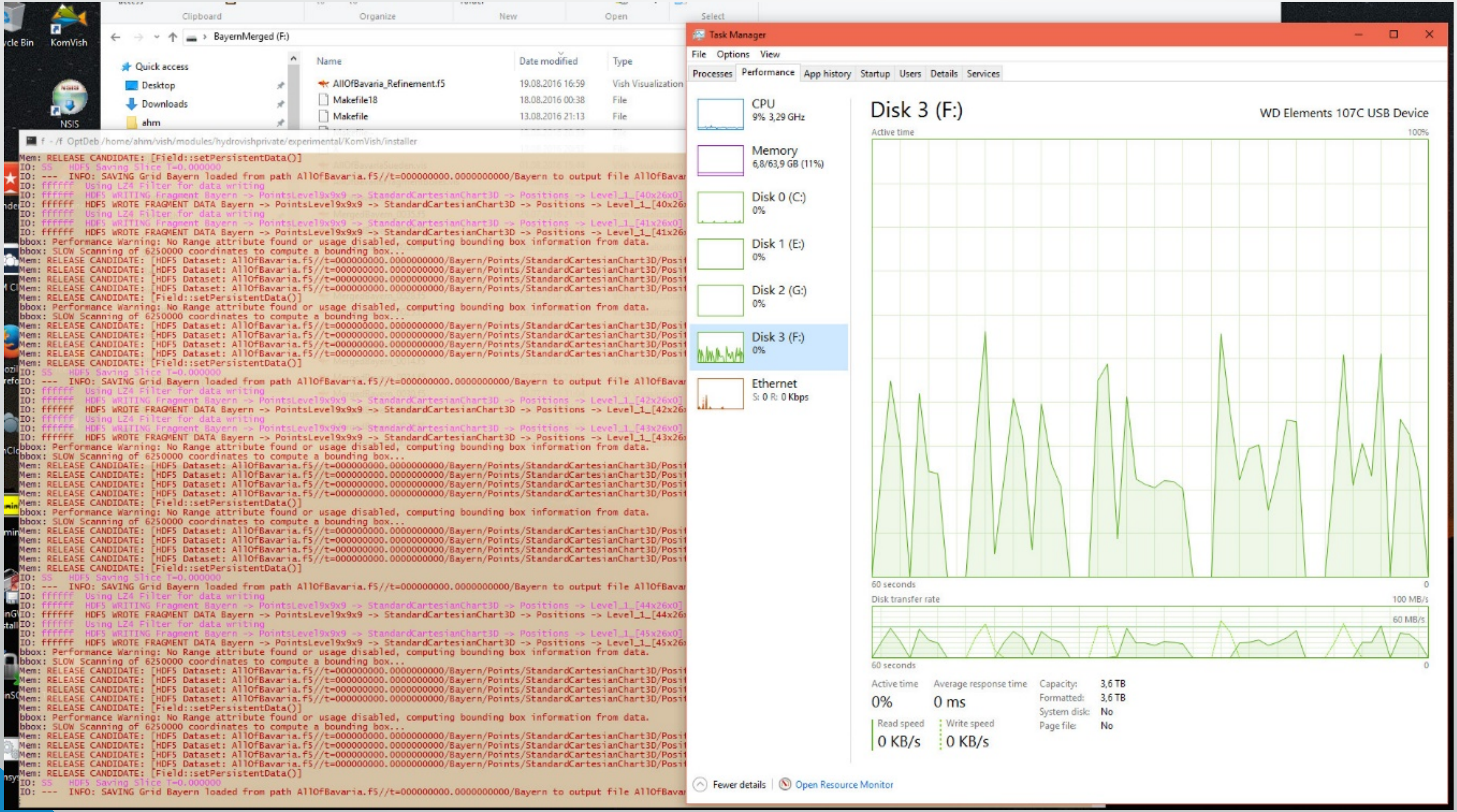

HDFView 2.11
File Window Tools Help
Recent Files C:\MinGW\msys\1.0\home\ahm\AHM\Bayern\MergedBayern_0005_Refinement.f5
Clear Text
MergedBayern_0005_Refinement.f5
Charts
TableOfContents
t=000000000.0000000000
Bayern
CellsSet
Charts
F5::TimeTable
Points
PointsLevel10x10x10
PointsLevel2x2x2
PointsLevel3x3x3
PointsLevel4x4x4
PointsLevel5x5x5
Positions
StandardCartesianChart3D
Positions
PointsLevel5x5x5
PointsLevel6x6x6
PointsLevel7x7x7
PointsLevel8x8x8
PointsLevel9x9x9
/ (48)
Group size = 3
Number of attributes = 0
Log Info
Metadata

Hierarchical References in F5

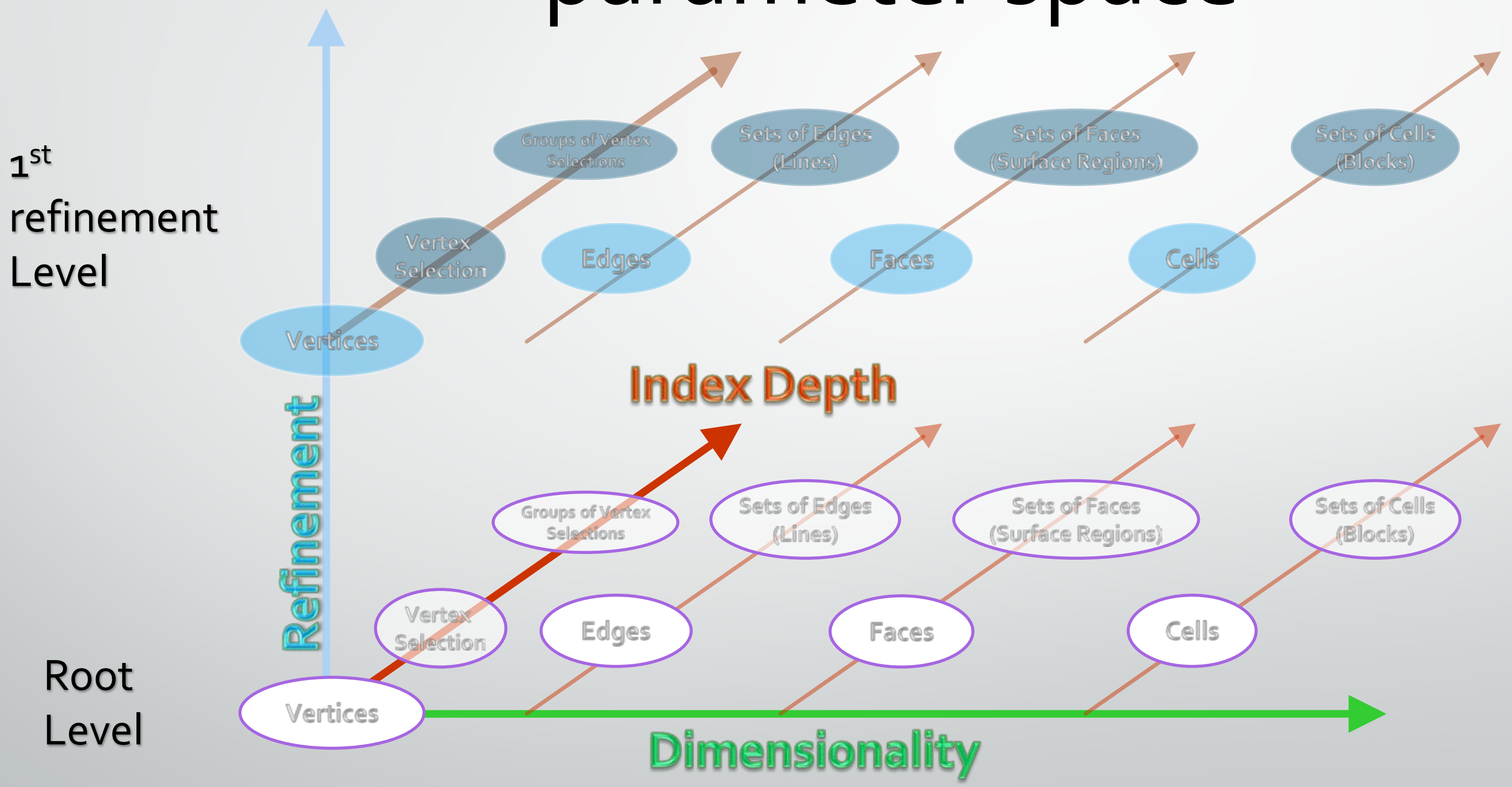




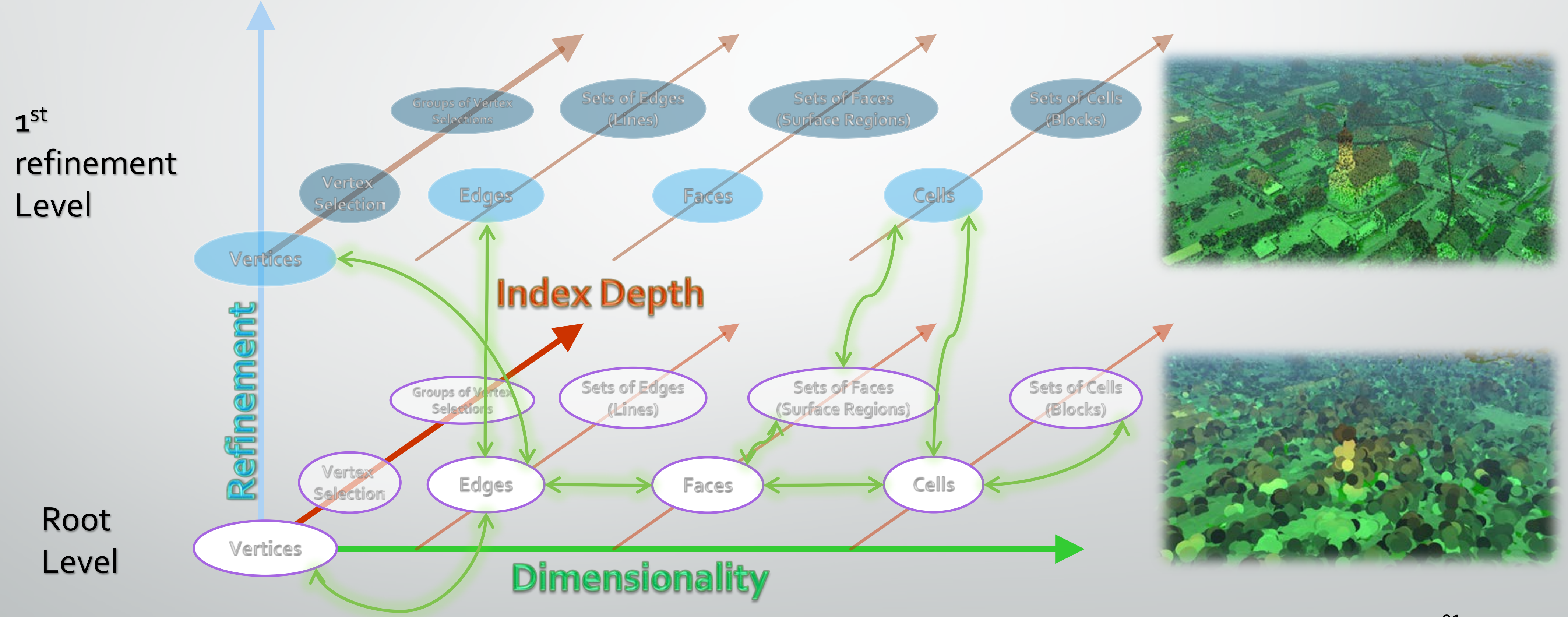
Data Processing – „Hierarchization“



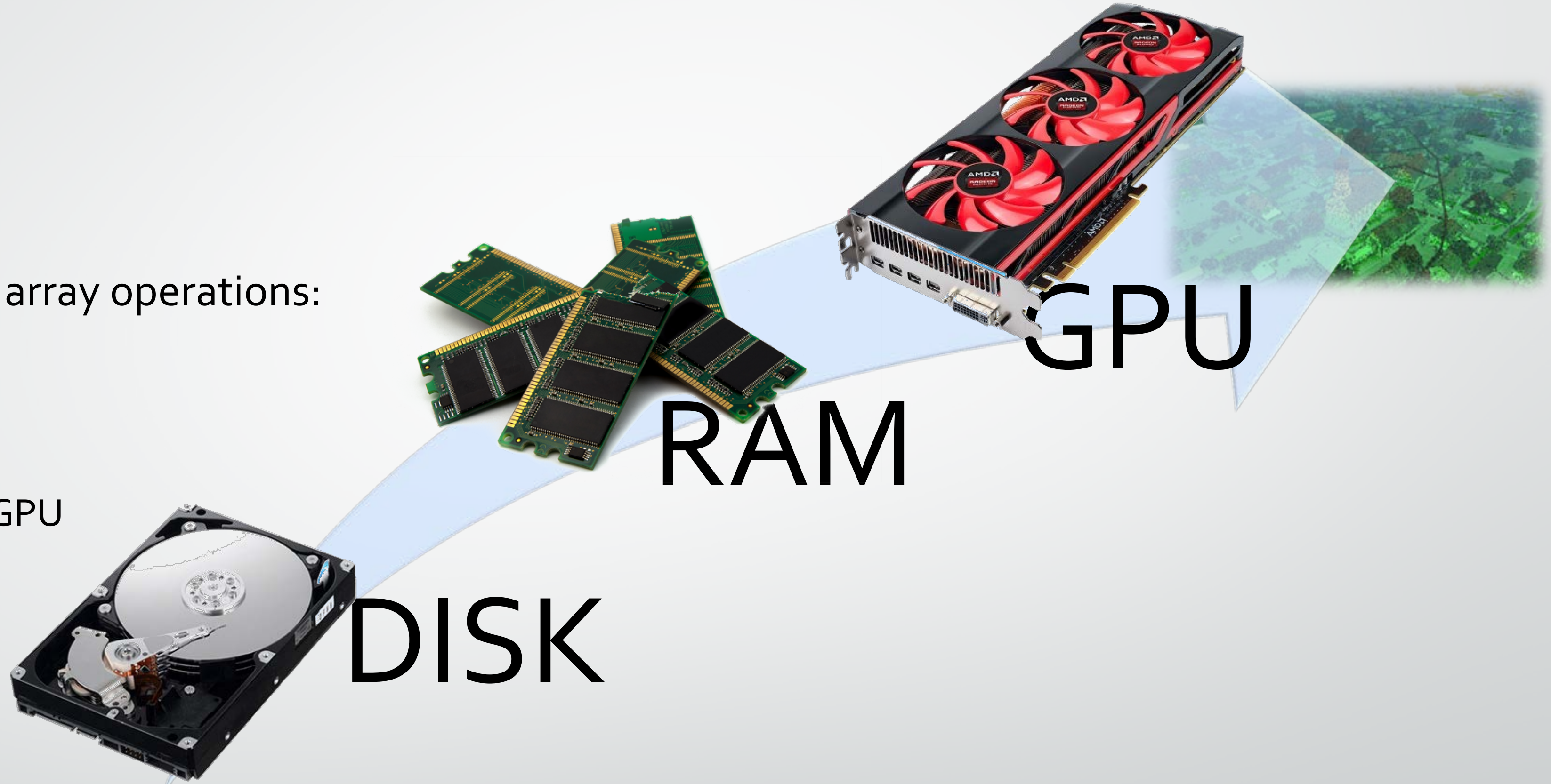
Skeletons as Fibers of a 3-dimensional parameter space



Relative Representations as Connectors between Skeletons



Arrays as High Performing Fiber Bundles



- Important: All operations are array operations:
  - Parallelizable
  - Fast I/O disk → RAM
  - Fast data transfer RAM → GPU
- *No pointer data structures*
  - Relative information via indices and arrays of indices
  - Optimized for visualization and data processing, not so much for data modification requiring rebuilding of index lists (e.g. surface editing)

GA for Massive Data

- Alignment of Point Clouds / Geometries / Images
- Feature detection / Point Classification / Object Identification
- Clustering of points for hierarchy generation
- Camera navigation & animation control
- …

“F5 Fiber Bundle Data Model”

- A property-based description of scientific data
- A specific data type is built from “construction blocks” (not enumerated case lists)
- Does not answer the question “*what is it?*” but answers the question(s) “*how is it?*”
- A specific data set can have properties of *many* data types
  - → non-exclusive properties
  - → eases/enhances interoperability
- Enables abstract operations independent of data type

Conclusion

- A data model for Unified Real-Time Visualization of Arbitrarily Massive Generic Scientific Data
- Commonalities across Grid types are not just enabled, they are unavoidable
- Simple data types have simple representations
- Complex data types are constructible from similar, reusable structures
- The F5 model does not cover *any* type of data, but a very wide range
- Geometric Algebra, Differential Geometry & Topology as foundation

Web References

- www.fiberbundle.net – The F5 Data model
- vish.fiberbundle.net – The Vish Visualization Shell (based on the F5 model)
- www.ahm.co.at – Airborne HydroMapping (LIDAR data acqusition & software development)
- www.aei.mpg.de – Max Planck Institute for Gravitational Physics

Demo: Lake Constance

www.ahm.co.at