2IMV20

Introduction and overview

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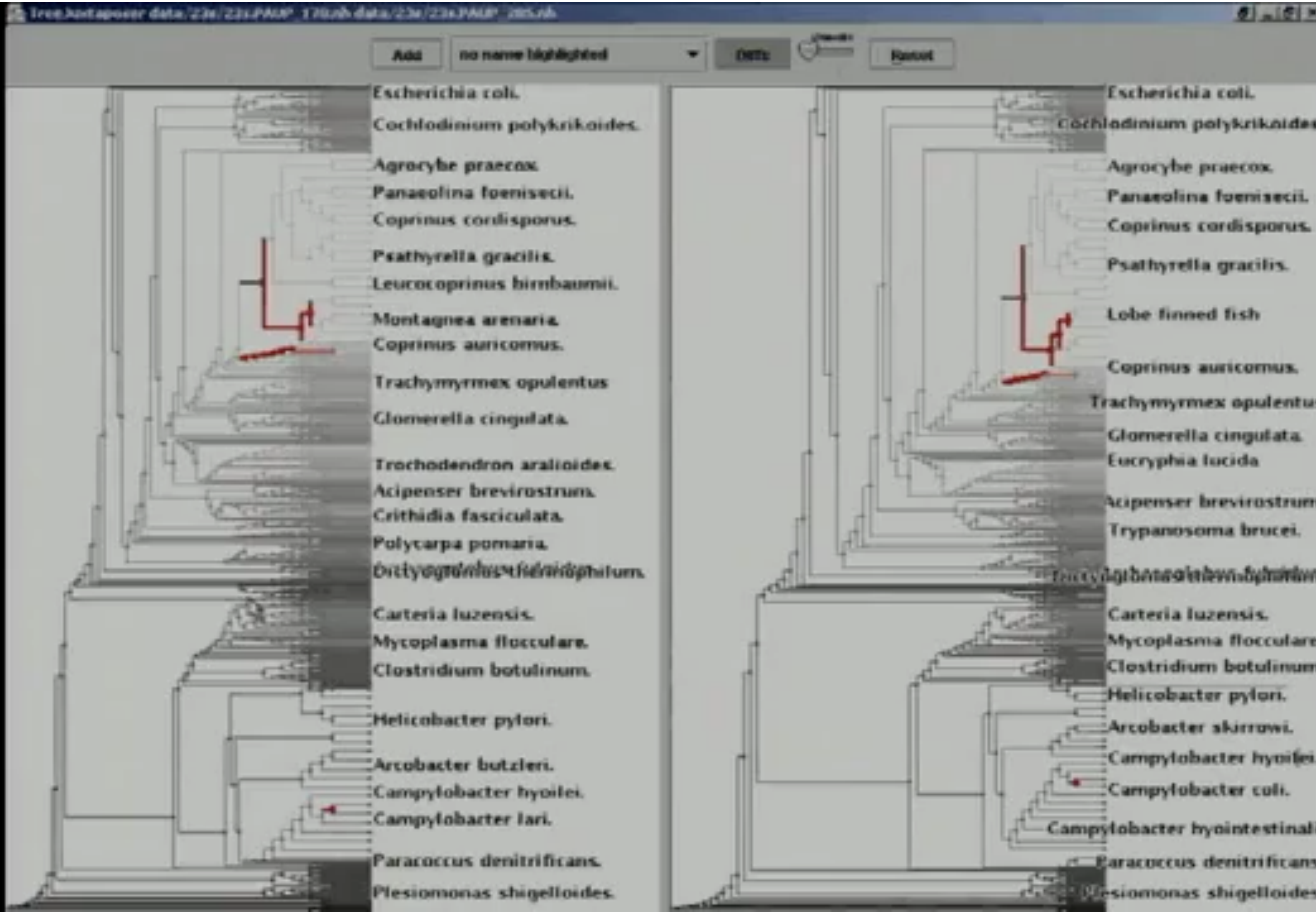
Eindhoven
University of Technology

What is visualization (vis)?

Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.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Escherichia coli.
Cochlodinium polykrikoides.
Agrocybe praecox.
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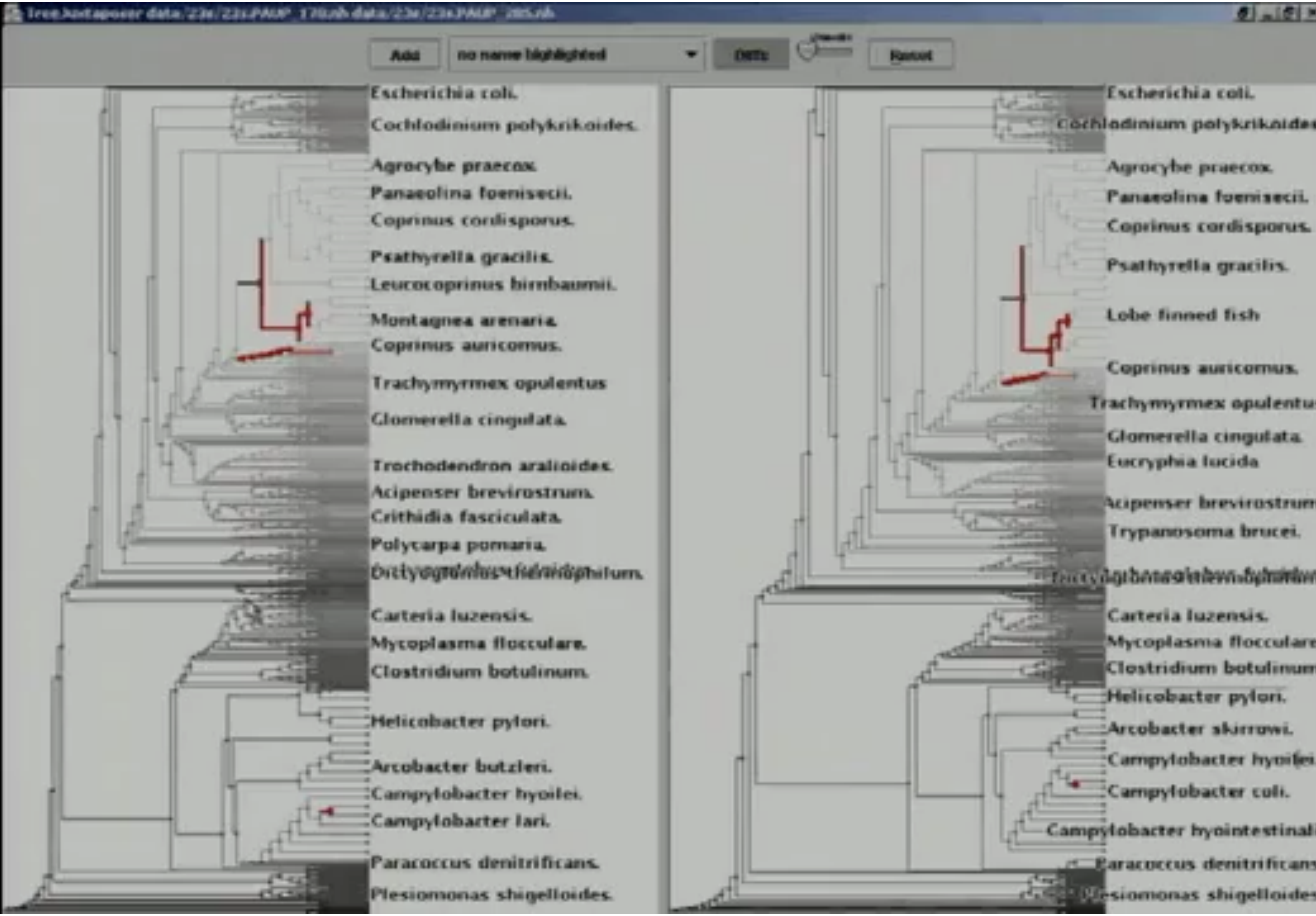
Psathyrella gracilis.
Leucocoprinus birnbaumii.
Montagnea arenaria.
Coprinus auricomus.
Trachymyrmex opulentus
Glomerella cingulata.
Trochodendron aralioides.
Acipenser brevirostrum.
Crithidia fasciculata.
Polycarpa pomaria.
Carteria luzensis.
Mycoplasma flocculare.
Clostridium botulinum.
Helicobacter pylori.
Arcobacter butzleri.
Campylobacter hyoilei.
Campylobacter lari.
Paracoccus denitrificans.
Plesiomonas shigelloides.
Escherichia coli.
Cochlodinium polykrikoides.
Agrocybe praecox.
Panaeolina foenisecii.
Coprinus cordisporus.
Psathyrella gracilis.
Lobe finned fish
Coprinus auricomus.
Trachymyrmex opulentus
Glomerella cingulata.
Eucryphia lucida
Acipenser brevirostrum.
Trypanosoma brucei.
Carteria luzensis.
Mycoplasma flocculare.
Clostridium botulinum.
Helicobacter pylori.
Arcobacter skirrowi.
Campylobacter hyoilei.
Campylobacter coli.
Campylobacter hyointestinali.
Paracoccus denitrificans.
Plesiomonas shigelloides.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Diffs
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Escherichia coli.
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Glomerella cingulata.
Trochodendron aralioides.
Acipenser brevirostrum.
Crithidia fasciculata.
Polycarpa pomaria.
Dictyoglomus thermophilum.
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Why a human in the loop?

Computer-based visualization systems provide **visual representations** of datasets designed to help **people** carry out **tasks** more effectively.

- For well-defined questions, computational techniques from statistics and machine learning often suffice
- Many analysis problems ill-specified
  - unclear what questions to ask upfront
- Use visualization to augment human capabilities

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Why a visual representation?

Computer-based visualization systems provide **visual representations** of datasets designed to help people carry out tasks more effectively.

- Visualization allows for offloading internal cognition and memory usage to the perceptual system
- Visual system is high-bandwidth channel to brain where a lot happens in parallel

Expression data table

Locus	Name ▲	TP 1	Sig 1	TP 2	Sig 2	TP 3	Sig 3	TP 4	Sig 4
BSU32000	dhbA	0.01747...	0.6641952	-0.07445...	0.4444011	0.3453729	0.03257...	-0.55759...	3.78186...
BSU01630	feuA	-0.60652...	5.01223...	0.1412761	0.4542625	0.1399248	0.3132094	-2.31015...	9.15853...
BSU33320	fhuD	-0.14566...	0.1348482	0.882993	2.69744...	0.8079552	3.36092...	-1.72154...	5.00349...
BSU23520	fur	-0.03155...	0.7082787	-0.14329...	0.03970...	-0.19986...	0.08716...	0.5835115	4.26215...
BSU08730	perR	-0.10198...	0.3840737	-0.19331...	0.1200347	-0.06772...	0.6129332	1.2947495	1.49797...
BSU25200	sigA	-0.16210...	0.05759...	-0.41637...	8.09213...	0.1925976	0.09284...	-0.06045...	0.7485786
BSU03800	yclN	-0.28458...	0.00193...	0.6180237	0.02774...	0.1462964	0.1909643	-0.73633...	5.48053...
BSU04530	ydbN	-0.17350...	0.03210...	0.5191455	0.1586233	1.756301	1.9832E-5	-1.03407...	0.0389274
BSU08480	yfhC	0.00294...	0.9764975	0.05548...	0.6965839	0.5974235	0.01224...	-1.08453...	1.82713...
BSU07850	yfkM	-0.01143...	0.8256124	0.2378585	0.01789...	0.04023...	0.6622004	0.5686641	0.00344...
BSU07520	yfmC	-0.141619	0.07512...	0.411437	0.02756...	0.1554271	0.1239295	-0.76515...	2.15553...

Westenberg et al., **Visualizing genome expression and regulatory network dynamics in genomic and metabolic context**. Computer Graphics Forum, 27(3):887–894, 2008.

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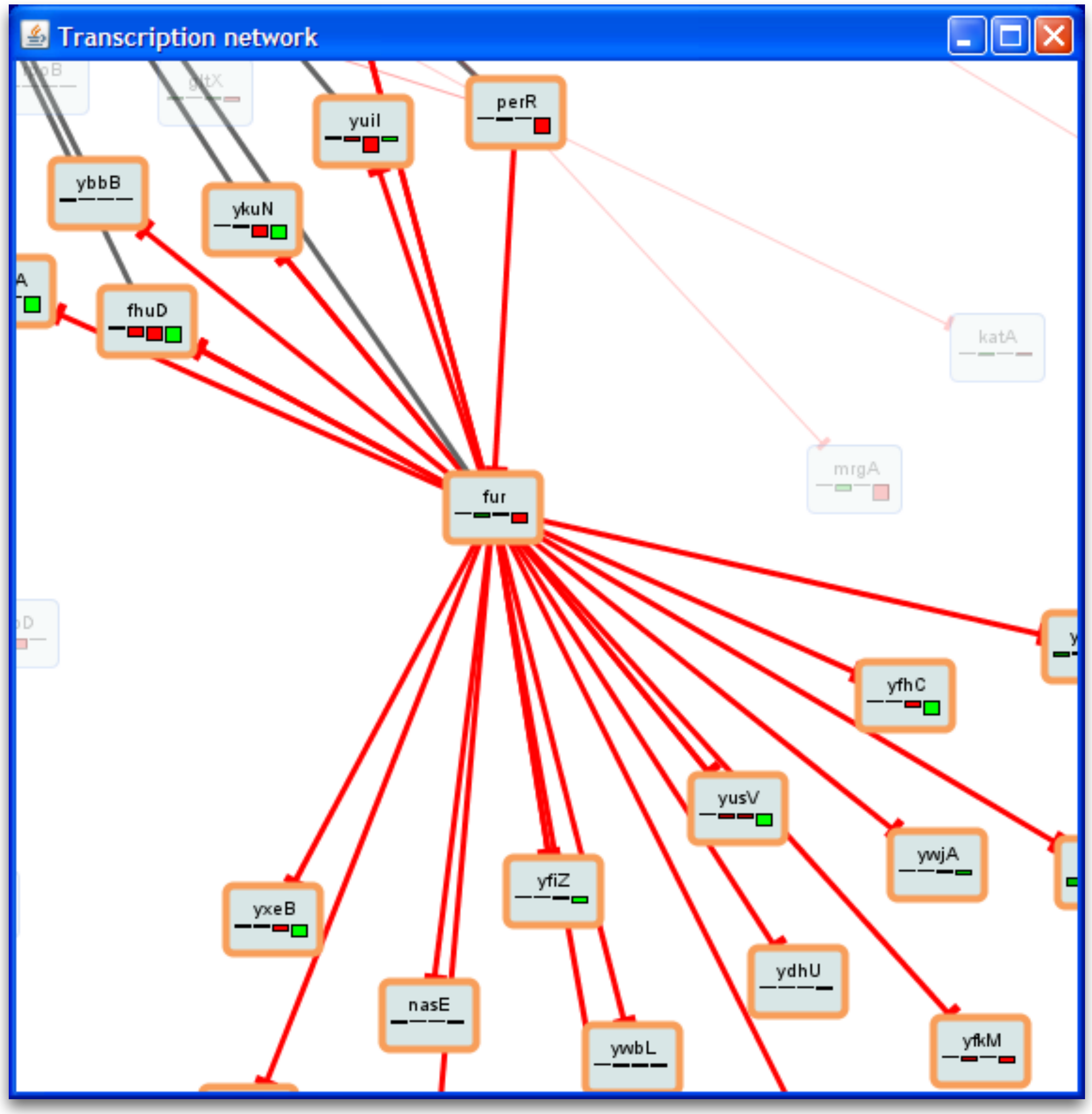

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Why focus on tasks and effectiveness?

Computer-based visualization systems provide visual representations of datasets designed to help people carry out **tasks** more **effectively**.

- Tasks provide a constraint on design
  - no visual representation supports all tasks
- Not all representations are effective
  - need to validate (hard)
  - design is unfortunately not an optimization process

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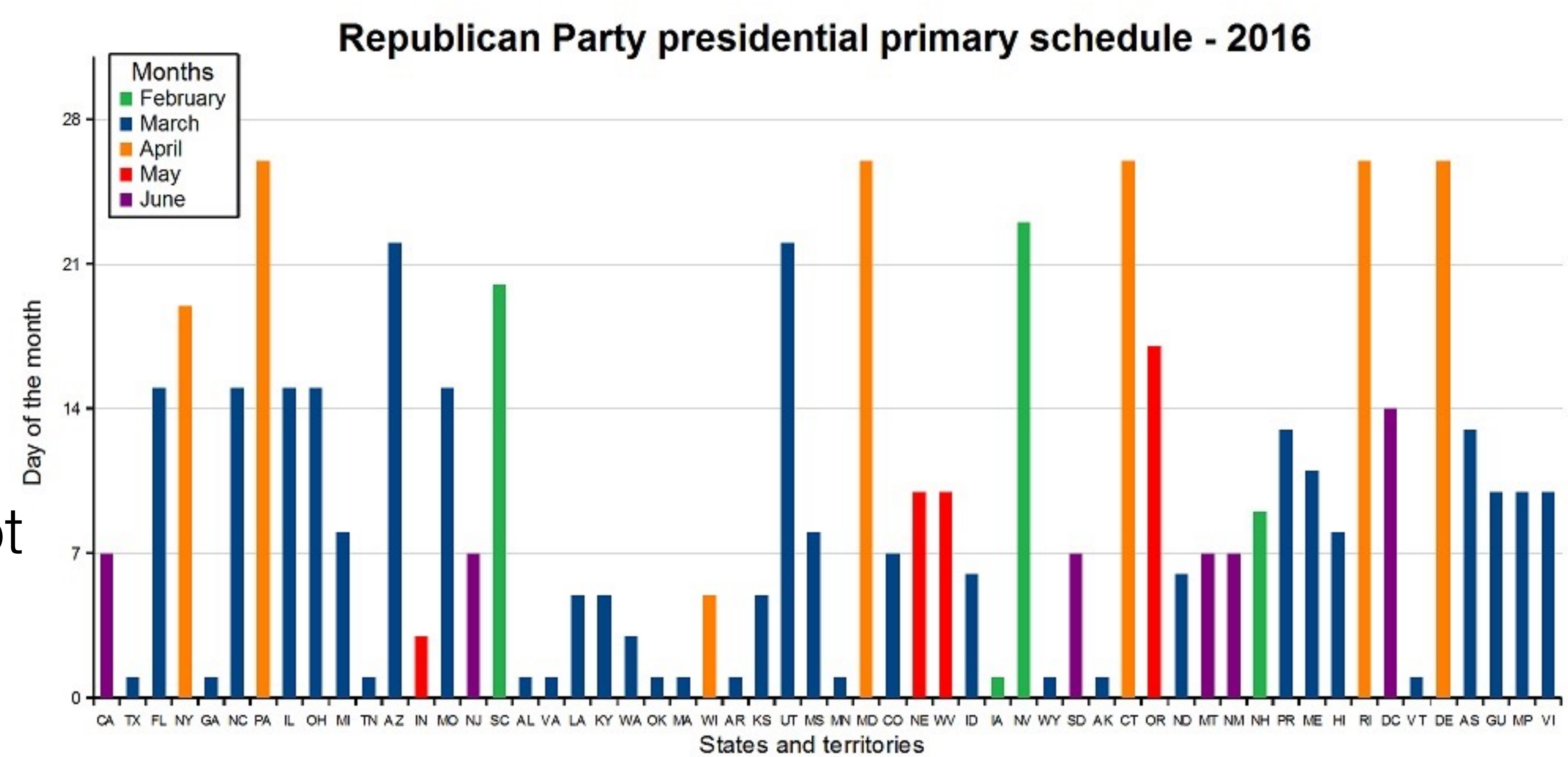

Why show data in detail?

- Summaries tend to lose information
  - true dataset structure is hidden
  - do not allow for data exploration to find patterns

Anscombe's Quartet

I		II		III		IV	
x	*y*	*x*	*y*	*x*	*y*	*x*	*y*
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.10	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.10	4	5.39	19	12.5
12	10.84	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

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x mean	9
x variance	10
y mean	7.5
y variance	3.75
x/y correlation	0.816

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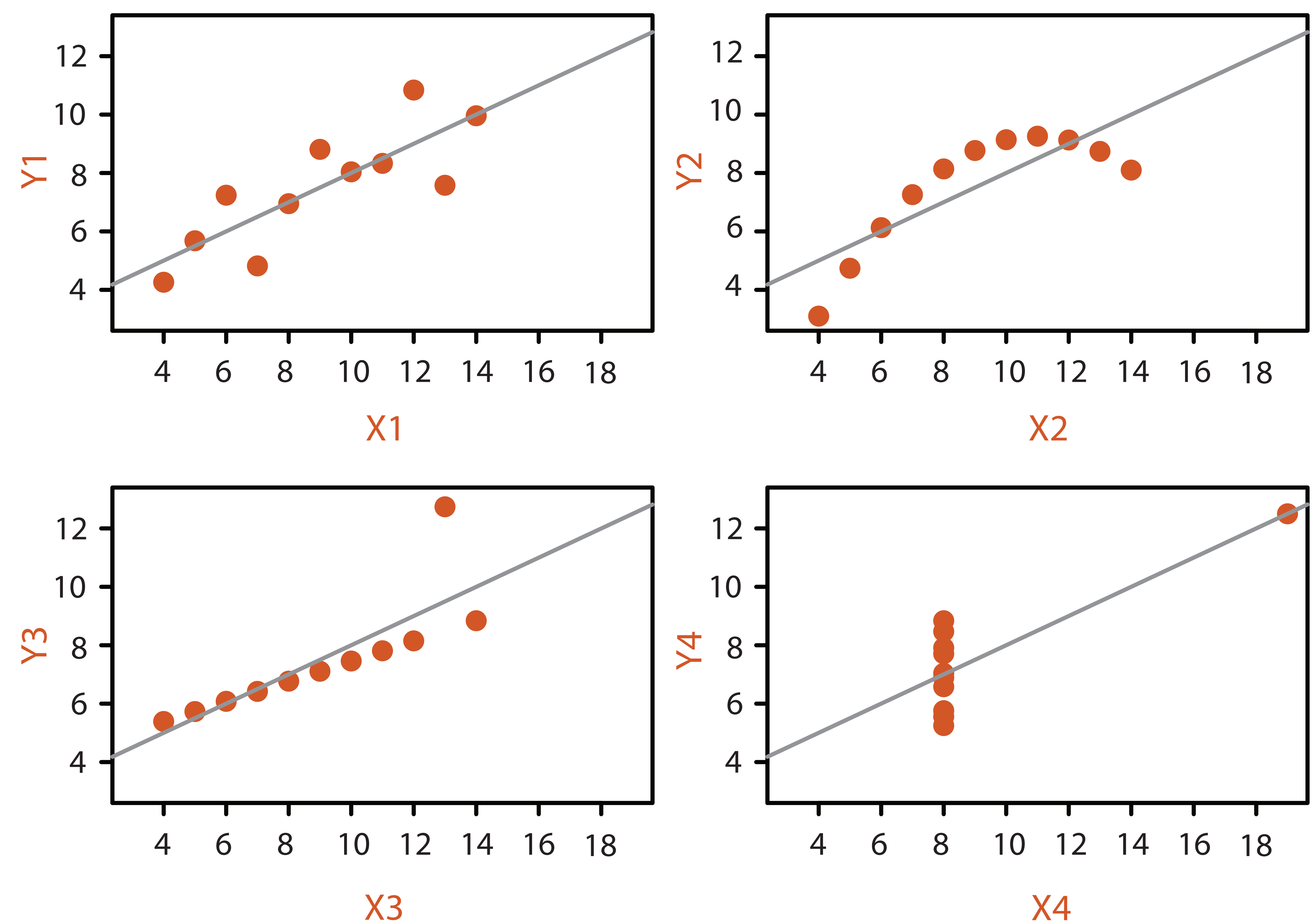

Why use interactivity?

- Deal with complexity
  - cannot show everything at once
- Single static view shows only one aspect
- Multiple levels of detail are often needed

Van den Elzen et al., **Small multiples, large singles: a new approach for visual data exploration.** Computer Graphics Forum 32(3):191-200, 2013.

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Validation is difficult

- How do you know if the visualization design works?
  - better?
  - faster?
  - more effectively?
  - get more insight?
- What sort of tasks do you need to evaluate a system?
  - intended users?
  - benchmark datasets?

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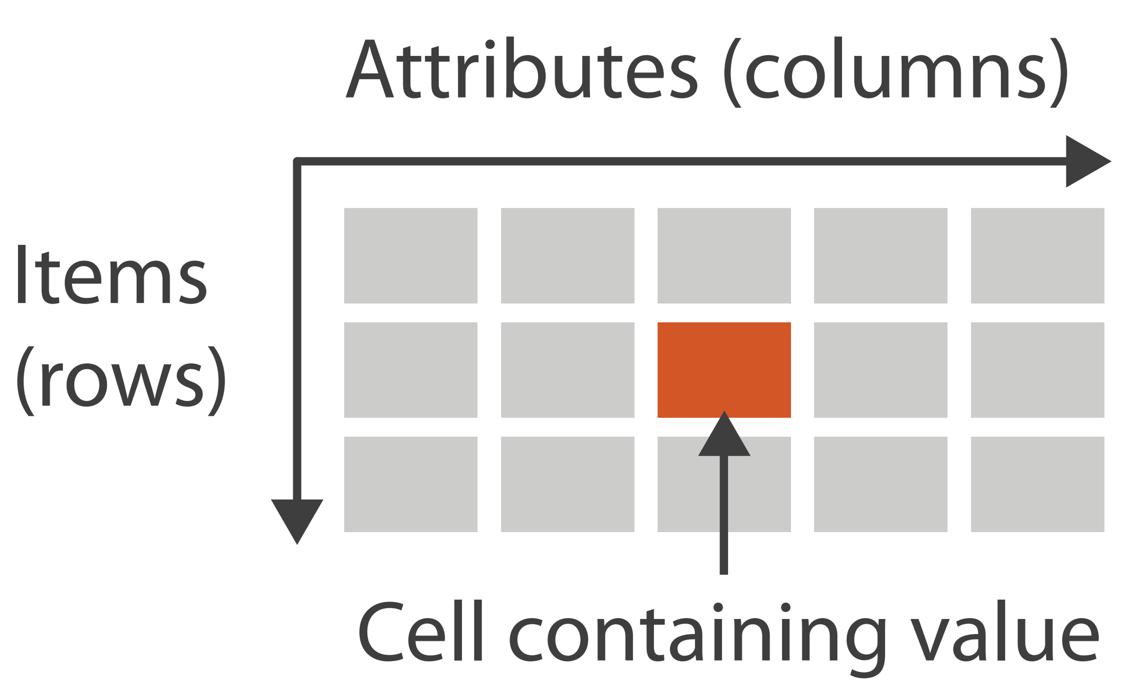
Design framework

- **What** is shown?
  - data abstraction
- **Why** is the user looking at it?
  - task abstraction
- **How** is it shown?
  - visual encoding and interaction

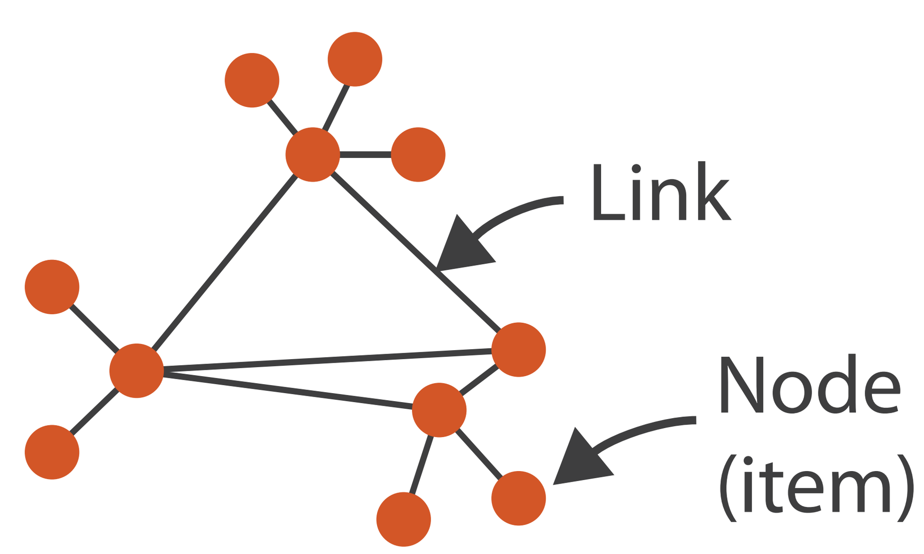
Munzner, **A nested model for visualization design and validation**. IEEE Trans. Visualization and Computer Graphics, 15(6):921-928, 2009.

What: Datasets and data types

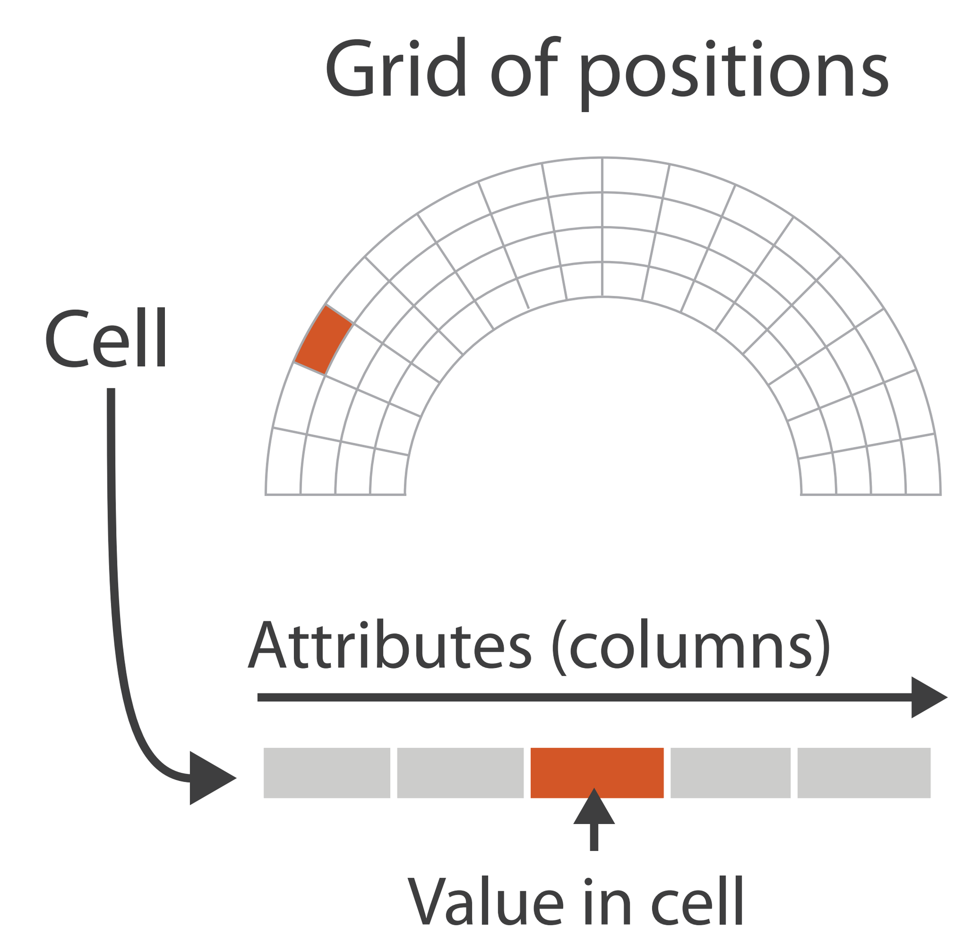
Tables



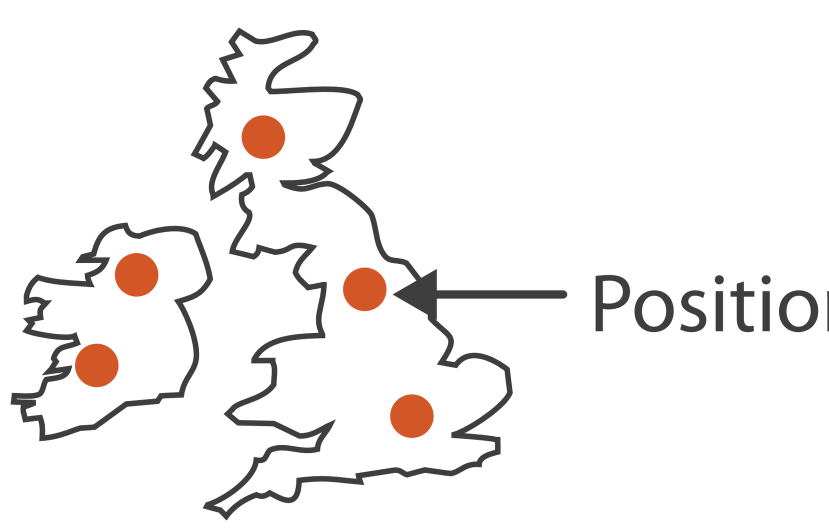
Networks



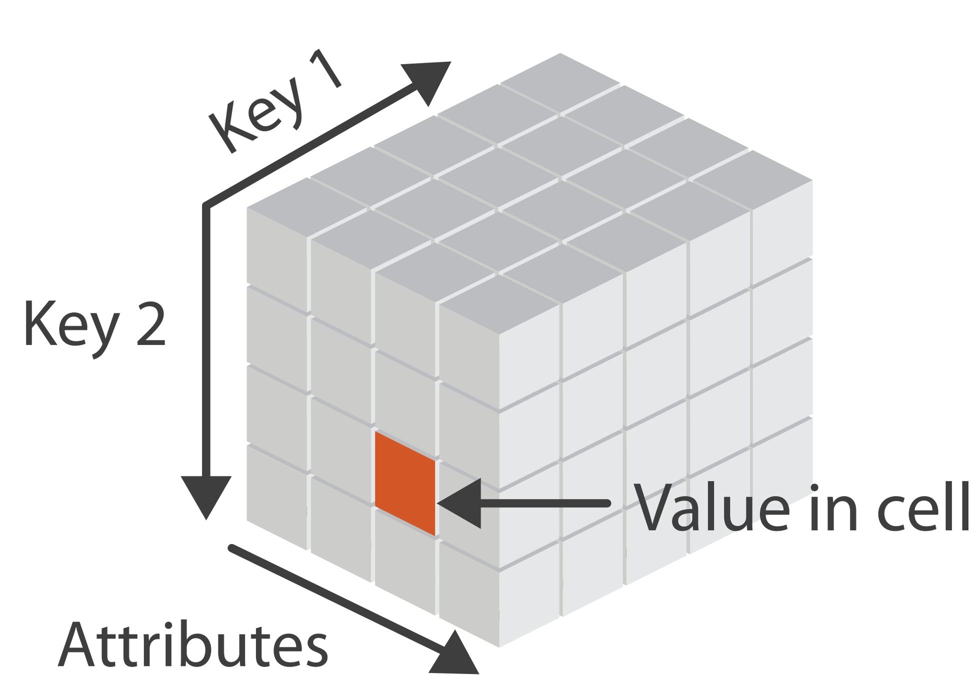
Fields



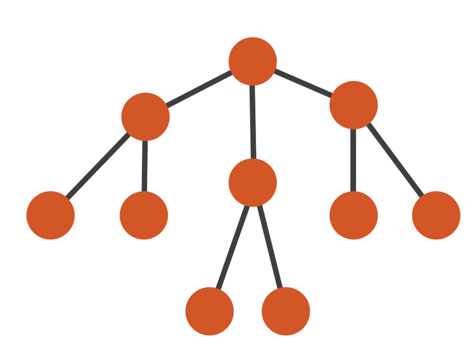
Geometry



Multi-dimensional table



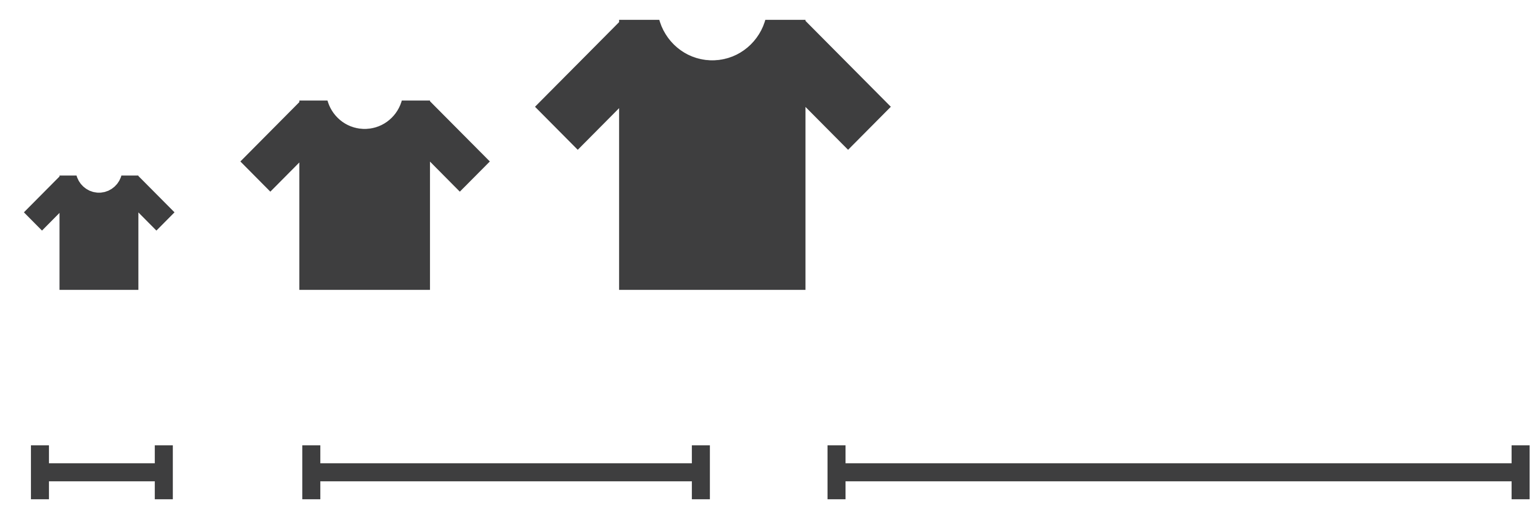
Trees



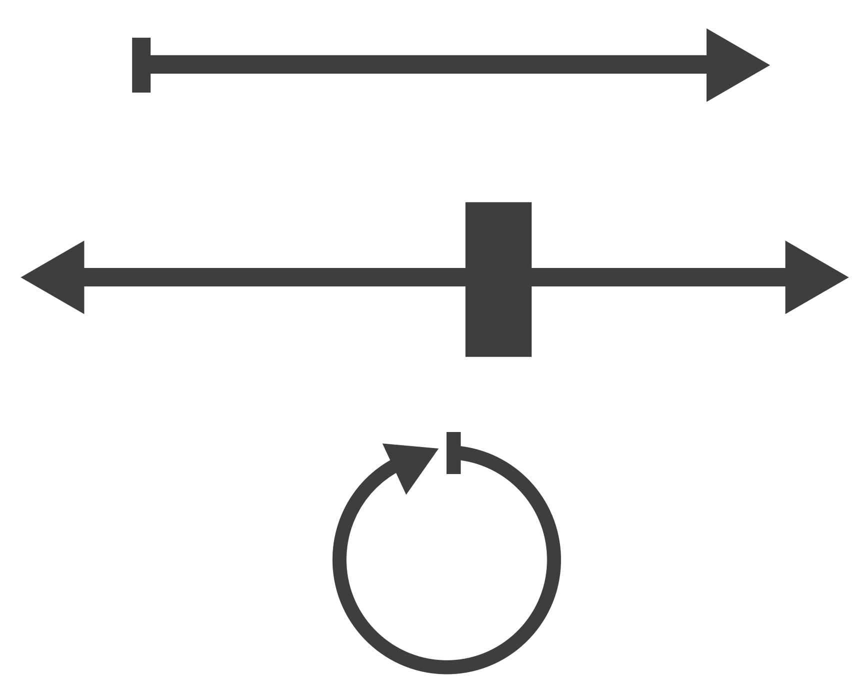
What: attribute types

- Categorical

- Ordered
  - ordinal
  - quantitative

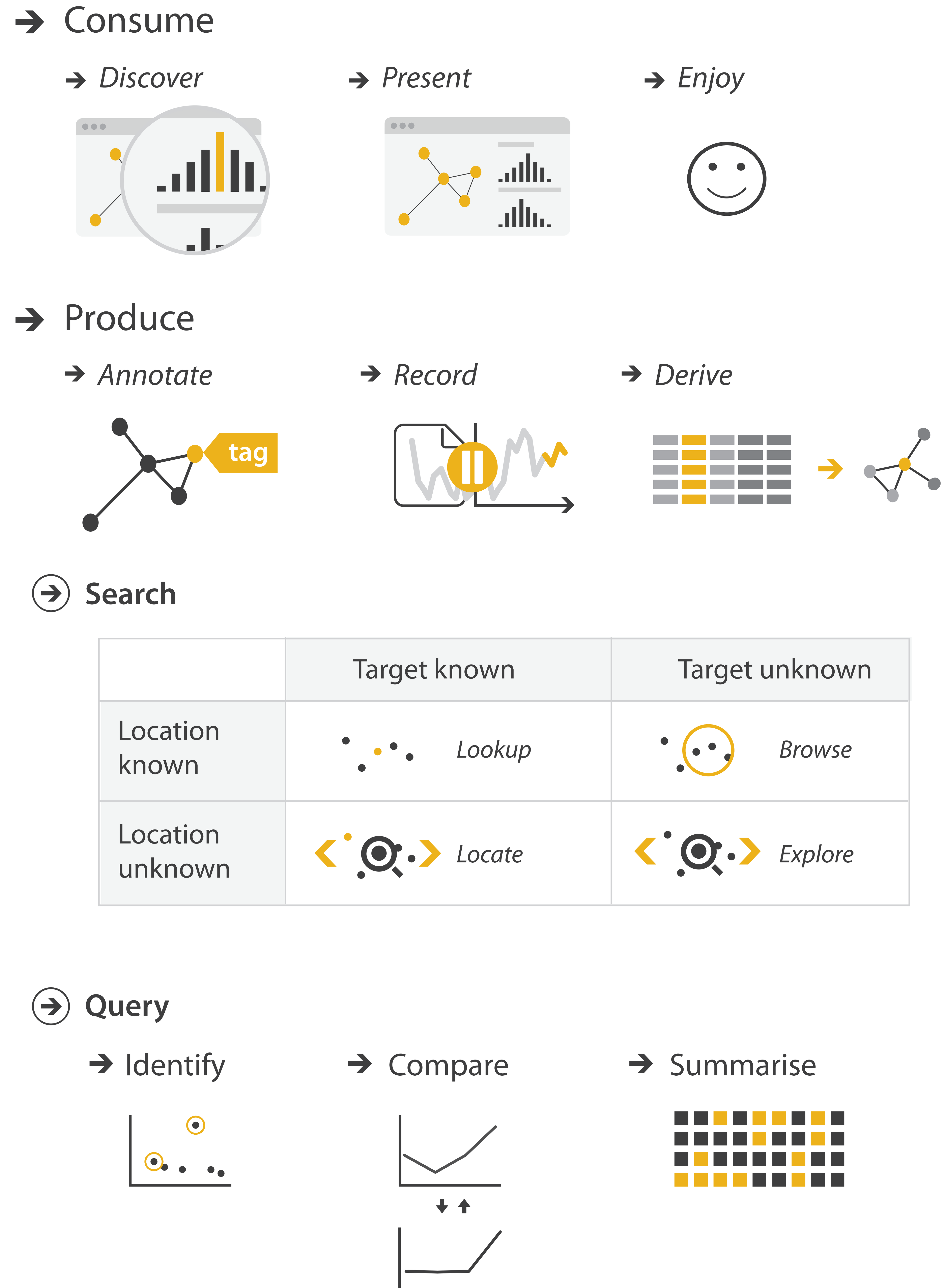


- Ordering direction
  - sequential
  - diverging
  - cyclic



Why: Tasks

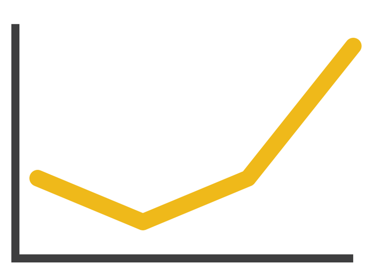
- User goals
  - High level actions: analyze
  - Mid level actions: search
  - Low level actions: query



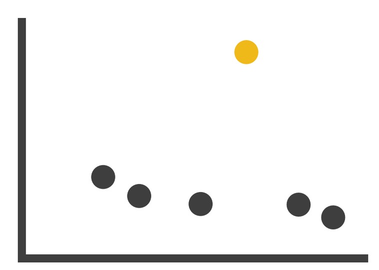
Why: Targets

ALL DATA

- Trends



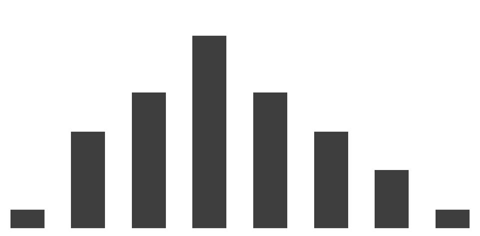
- Outliers



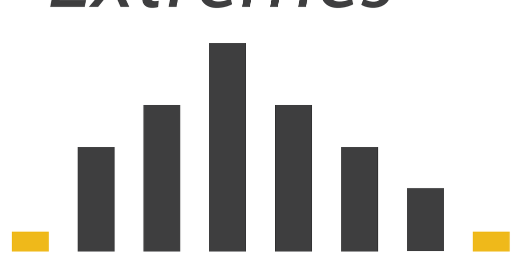
- Features

ATTRIBUTES

- One
  - *Distribution*

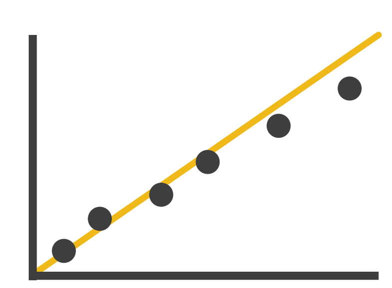


  - *Extremes*

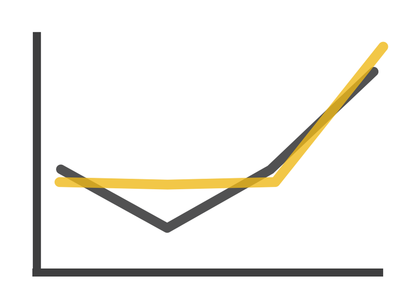


- Many
  - *Dependency*

  - *Correlation*

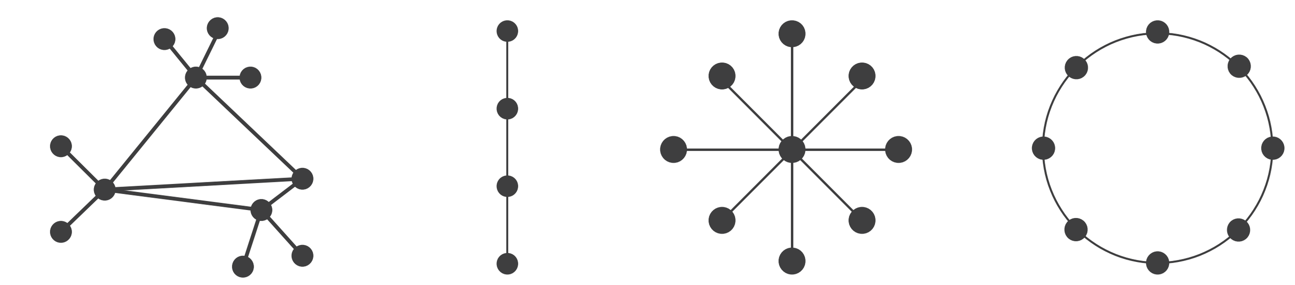


  - *Similarity*

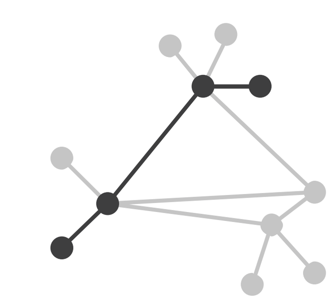


NETWORK DATA

- Topology

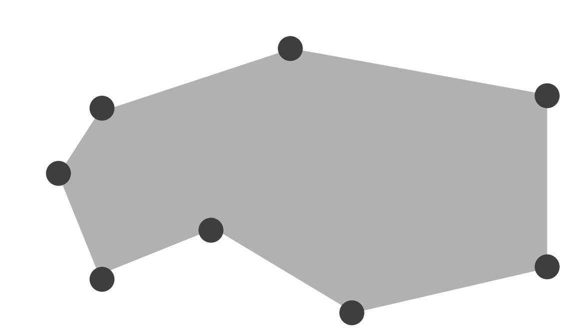


  - *Paths*



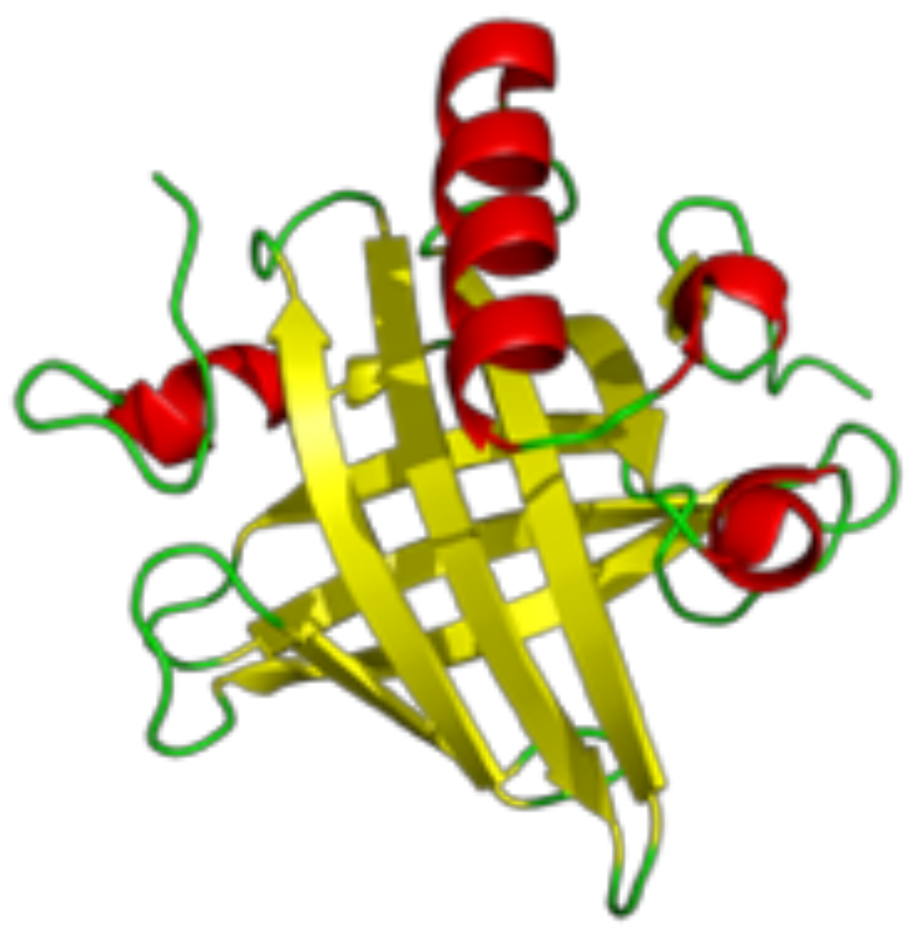
SPATIAL DATA

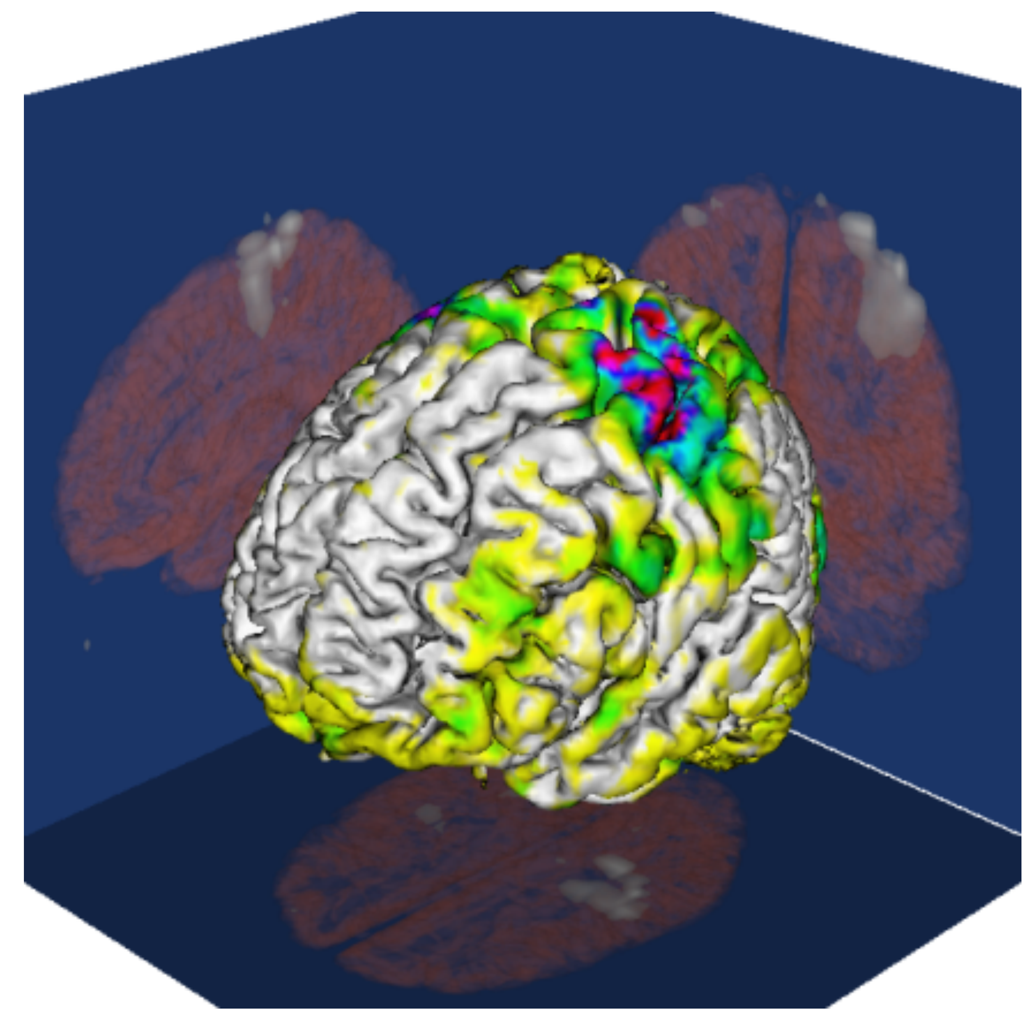
- Shape

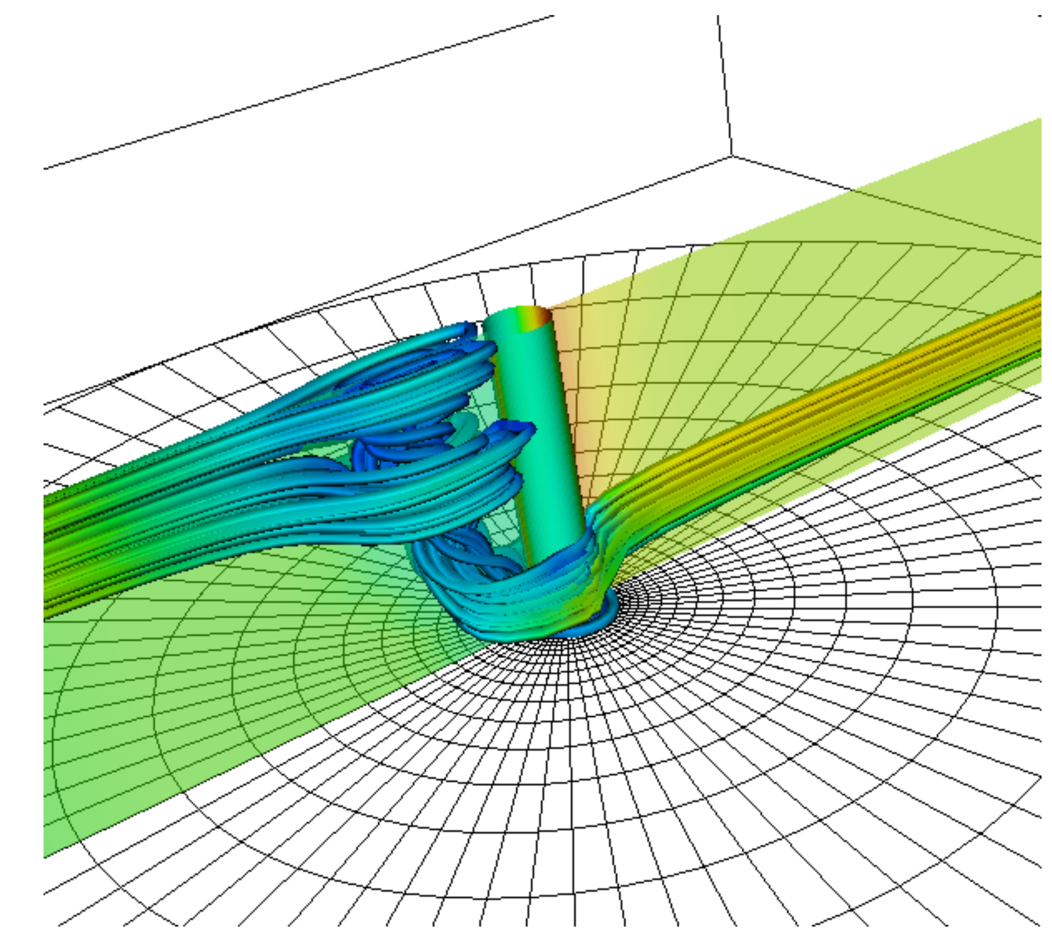


Design space

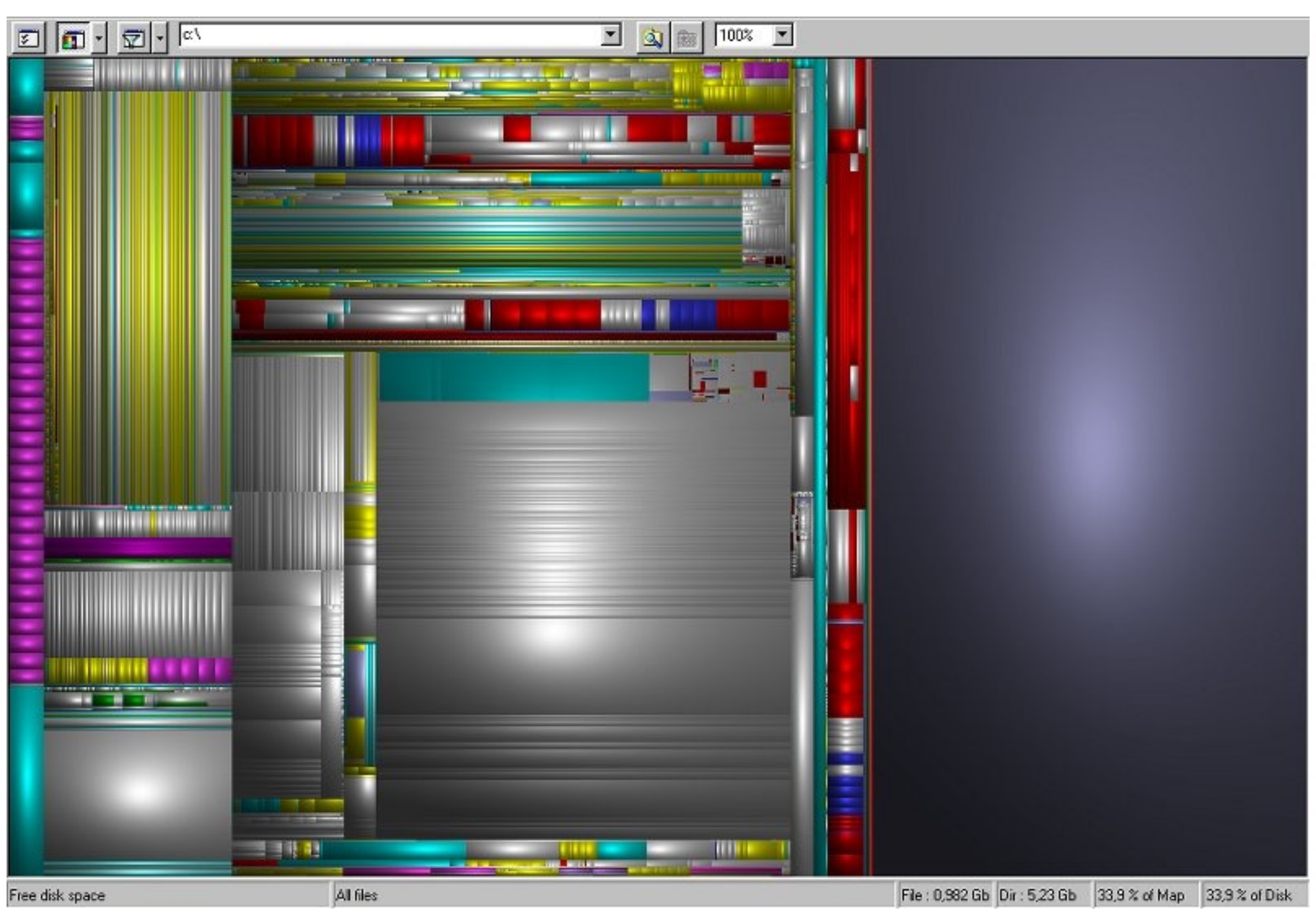
- Physical data - Scientific visualization (SciVis)

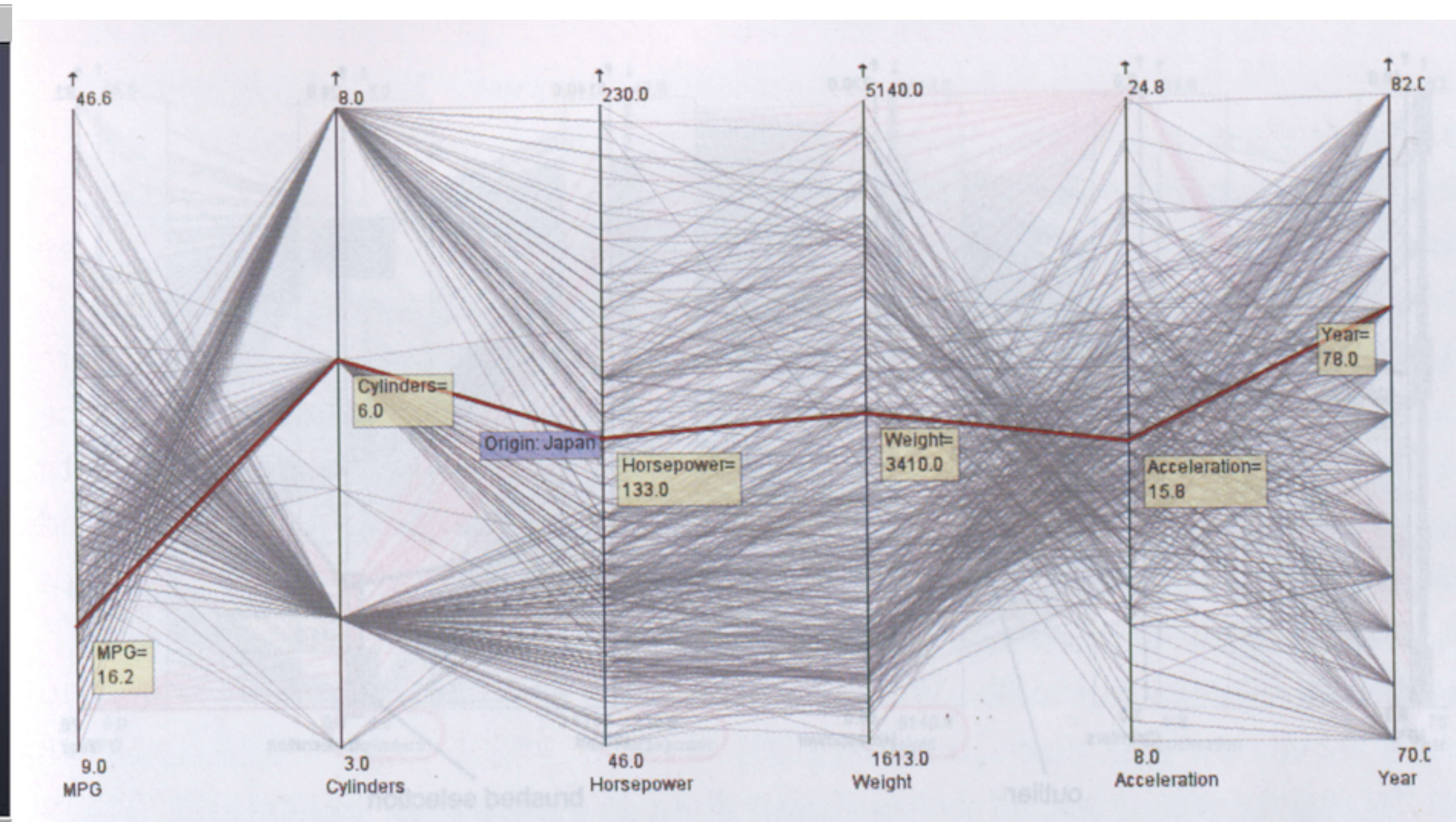






- Abstract data - Information visualization (InfoVis)





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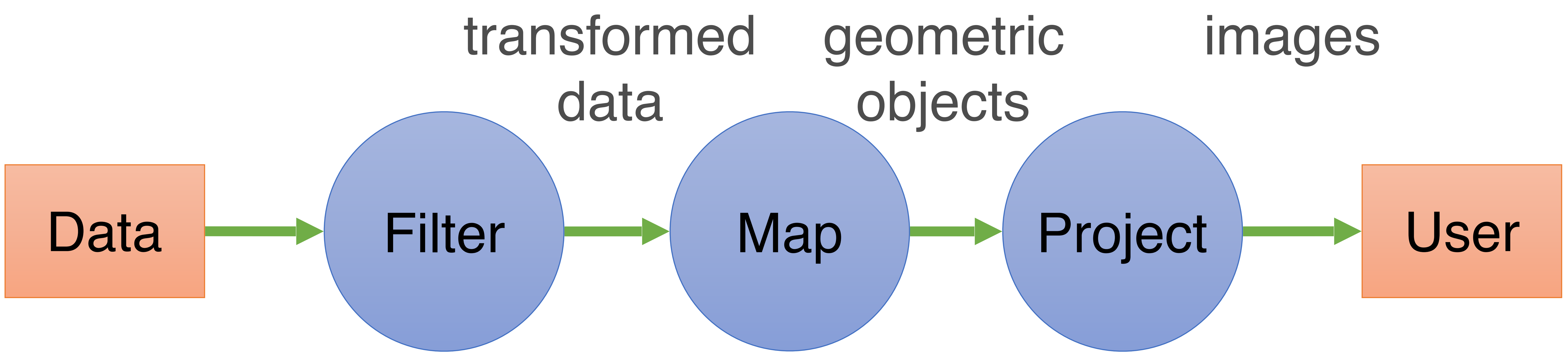
Visualization pipeline



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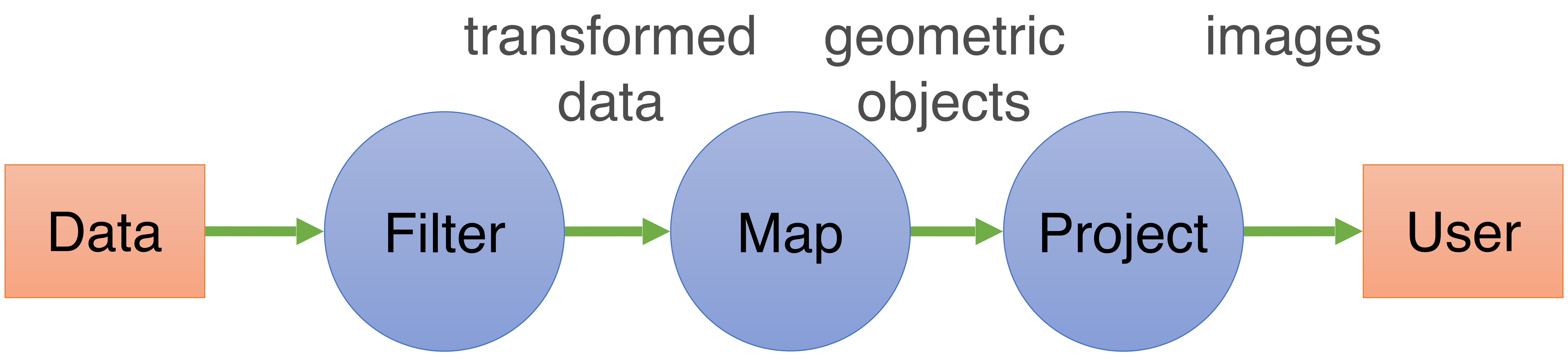
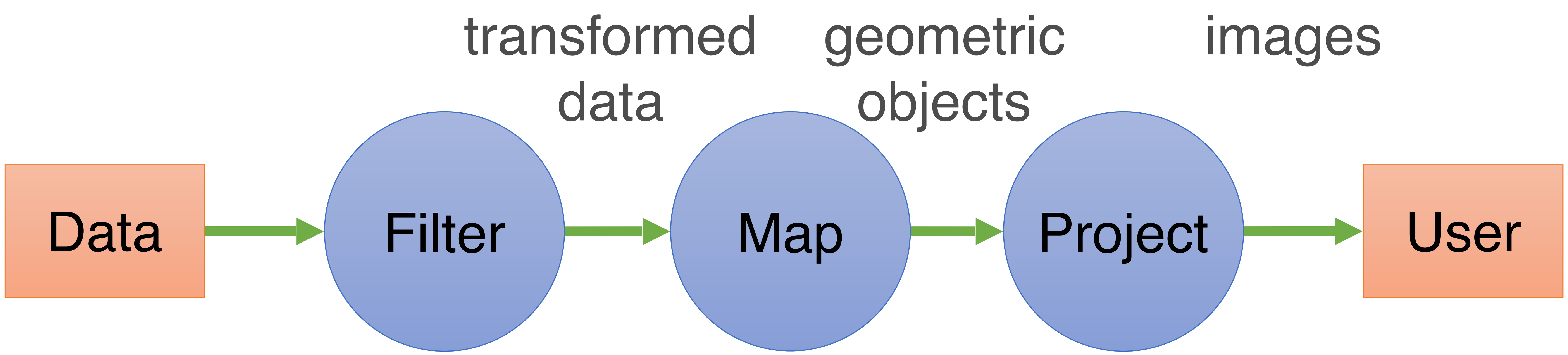


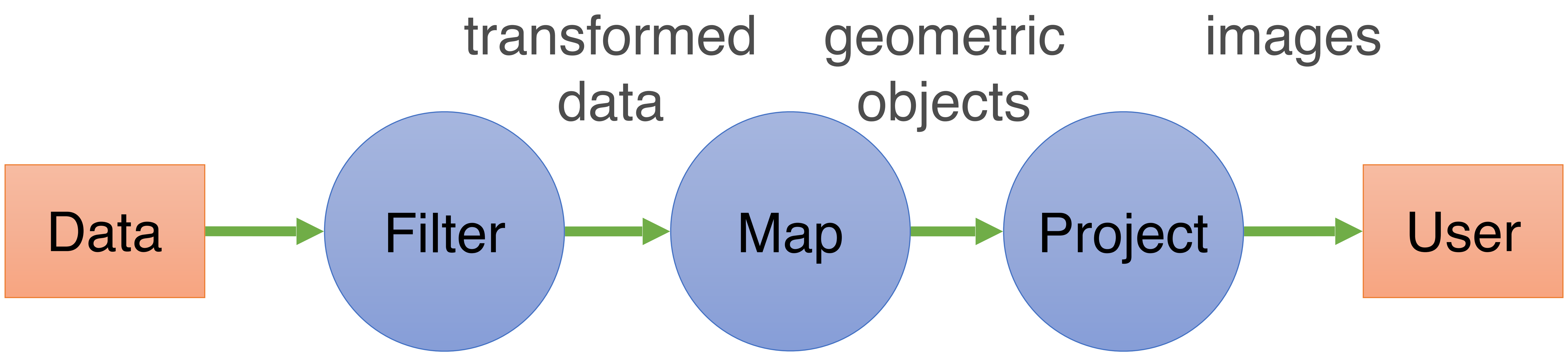
NL: 3000
UK: 12
D: 14
F: 17
I: 5
…

Visualization pipeline



NL: 3000	UK: 25%
UK: 12	D: 29%
D: 14	F: 35%
F: 17	I: 10%
I: 5	…
…	

Visualization pipeline



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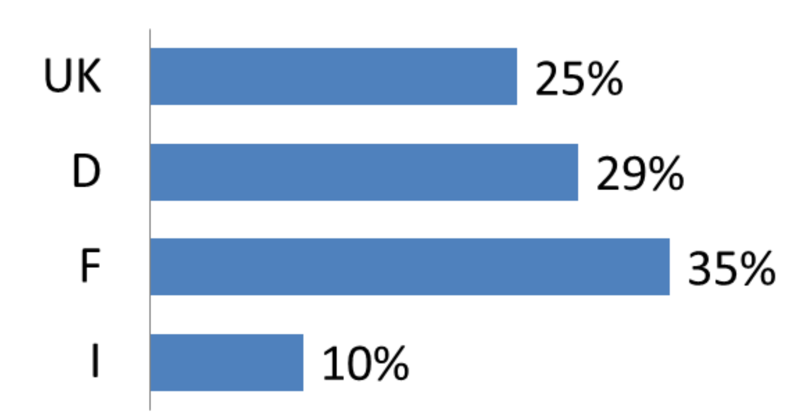
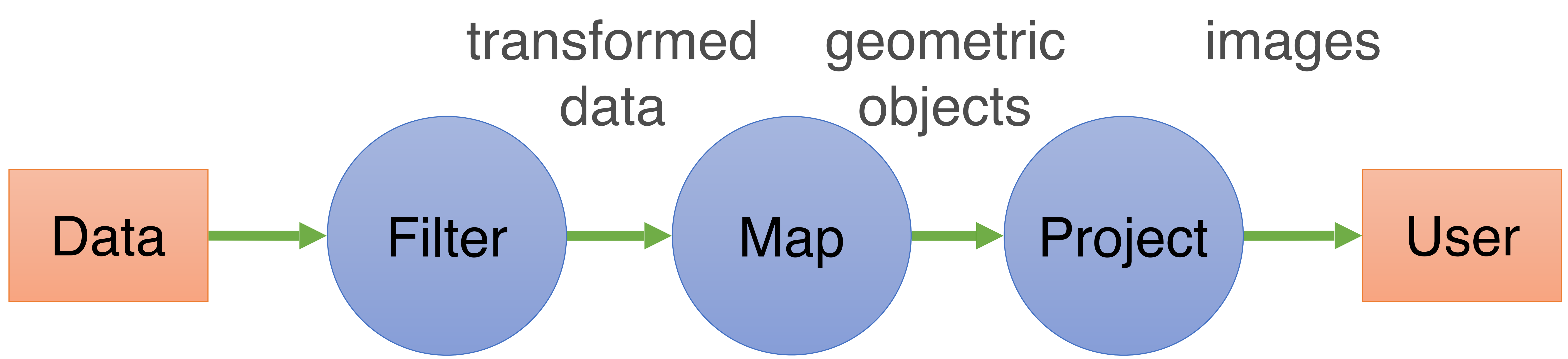
I: 10%
…

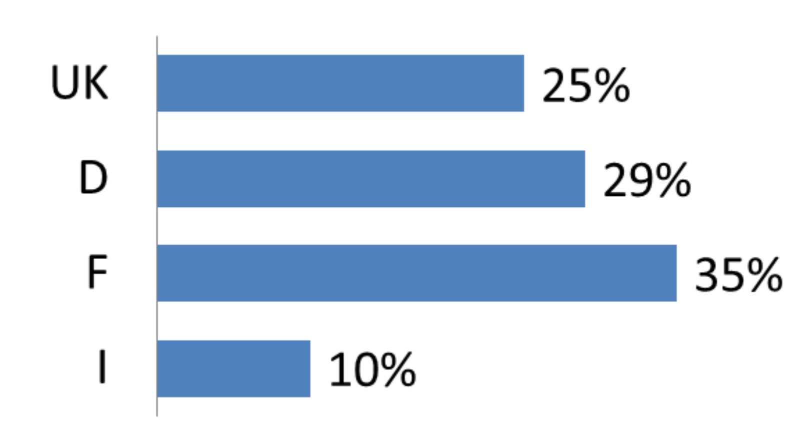


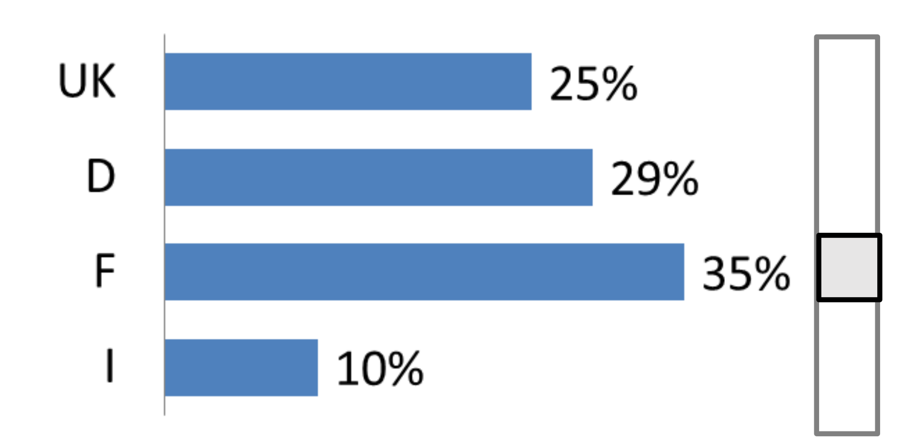
Visualization pipeline



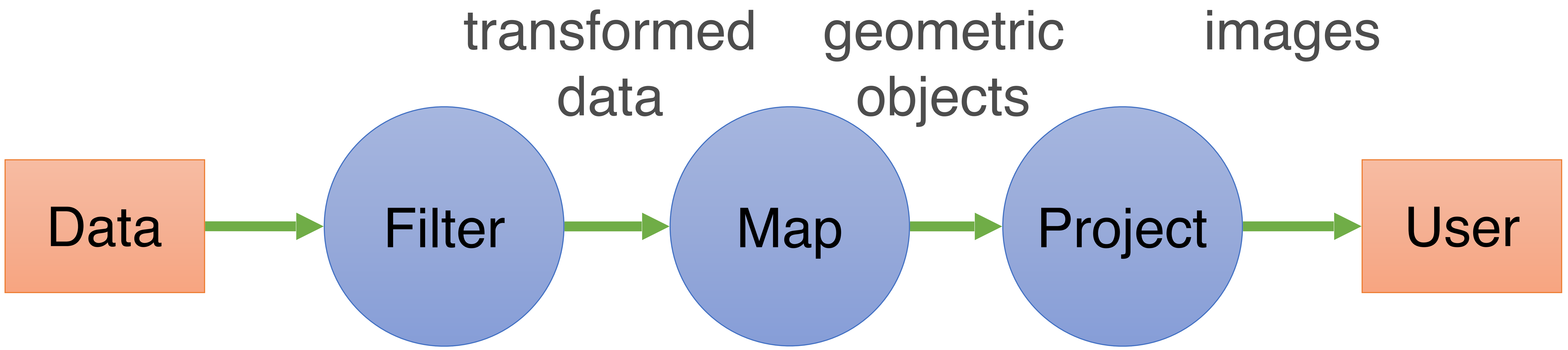
NL: 3000
UK: 12
D: 14
F: 17
I: 5
…

UK: 25%
D: 29%
F: 35%
I: 10%
…

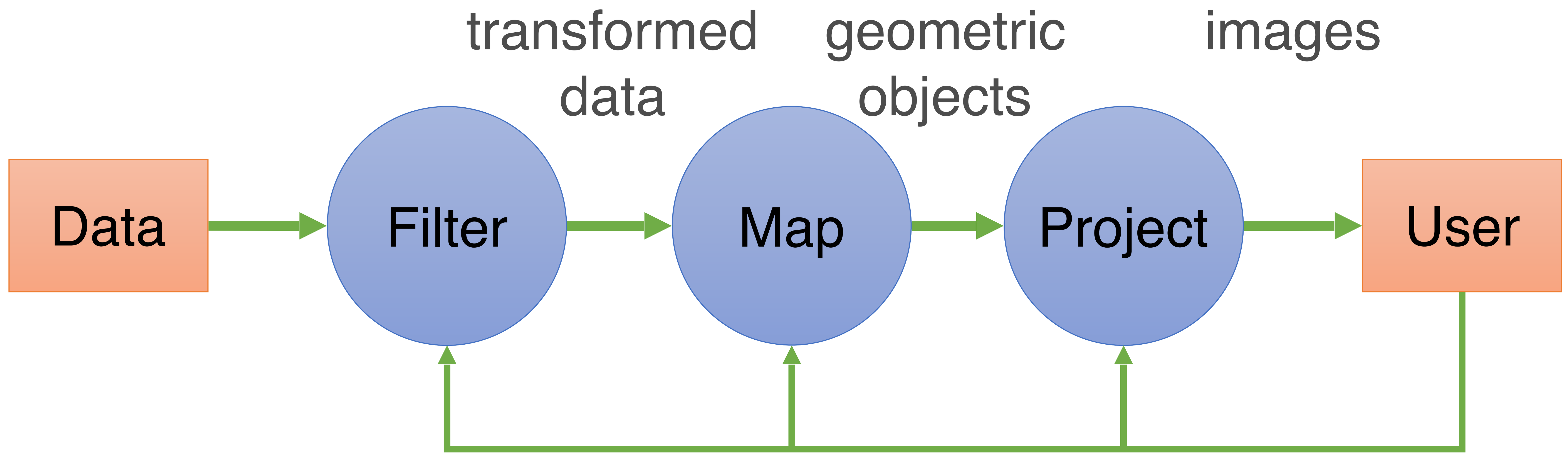




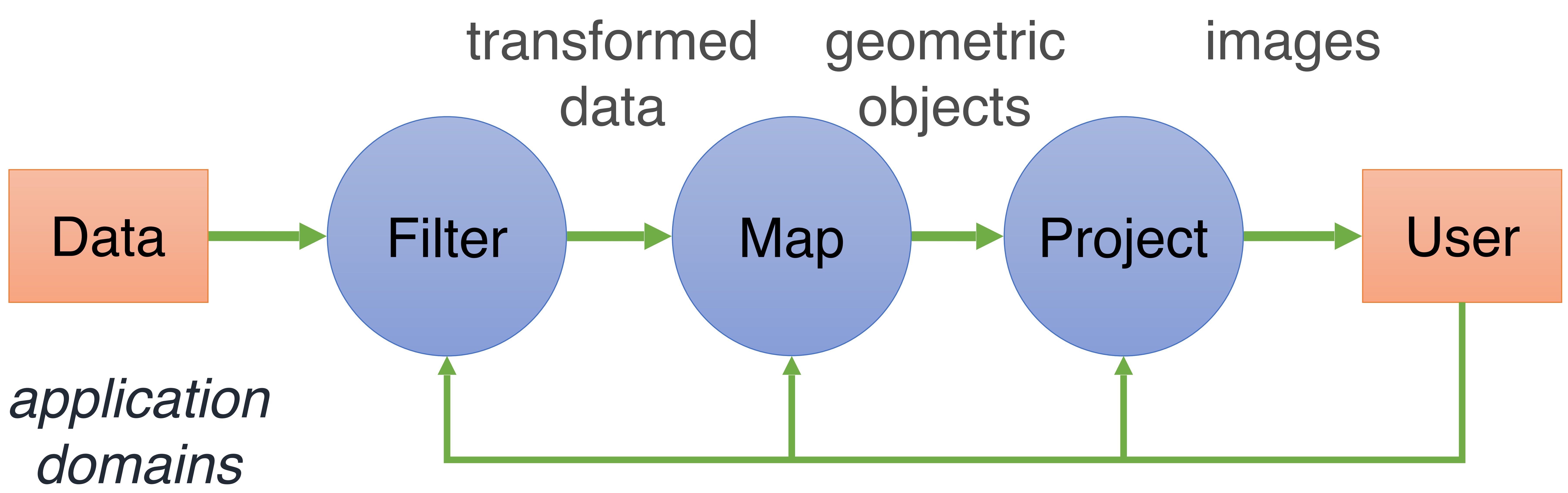
Visualization pipeline



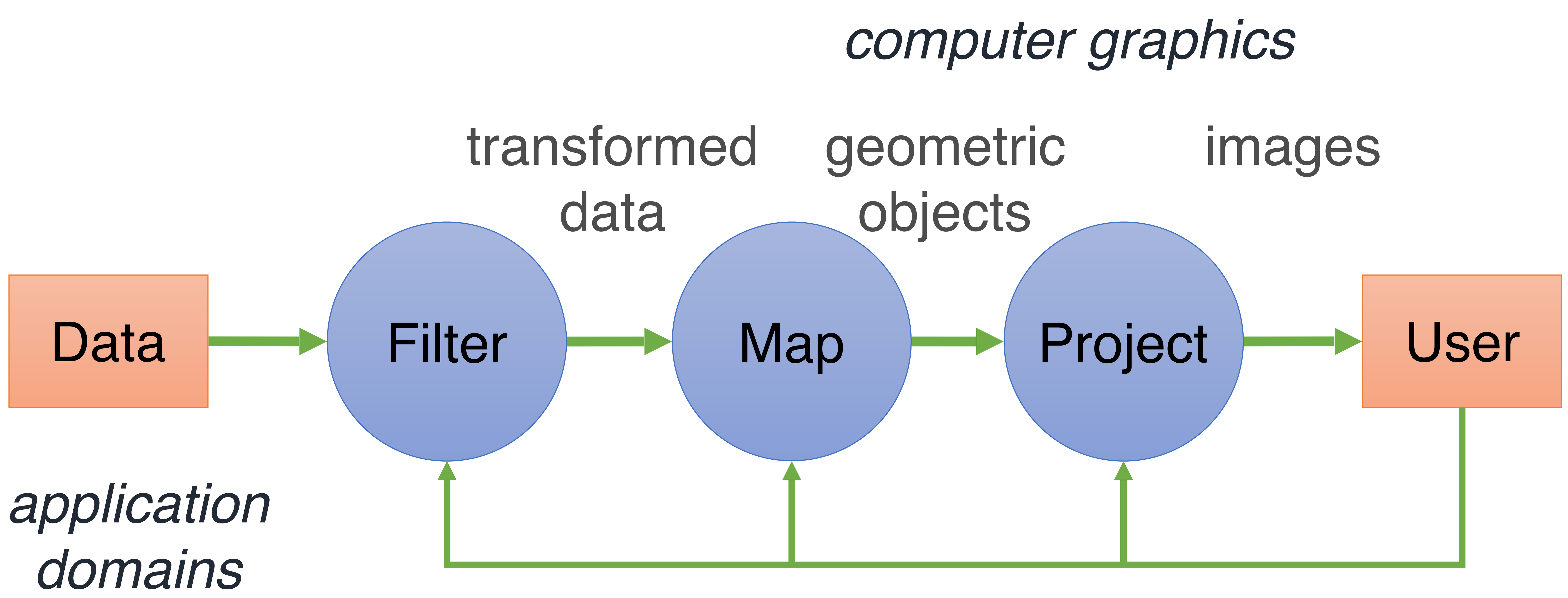
Visualization pipeline



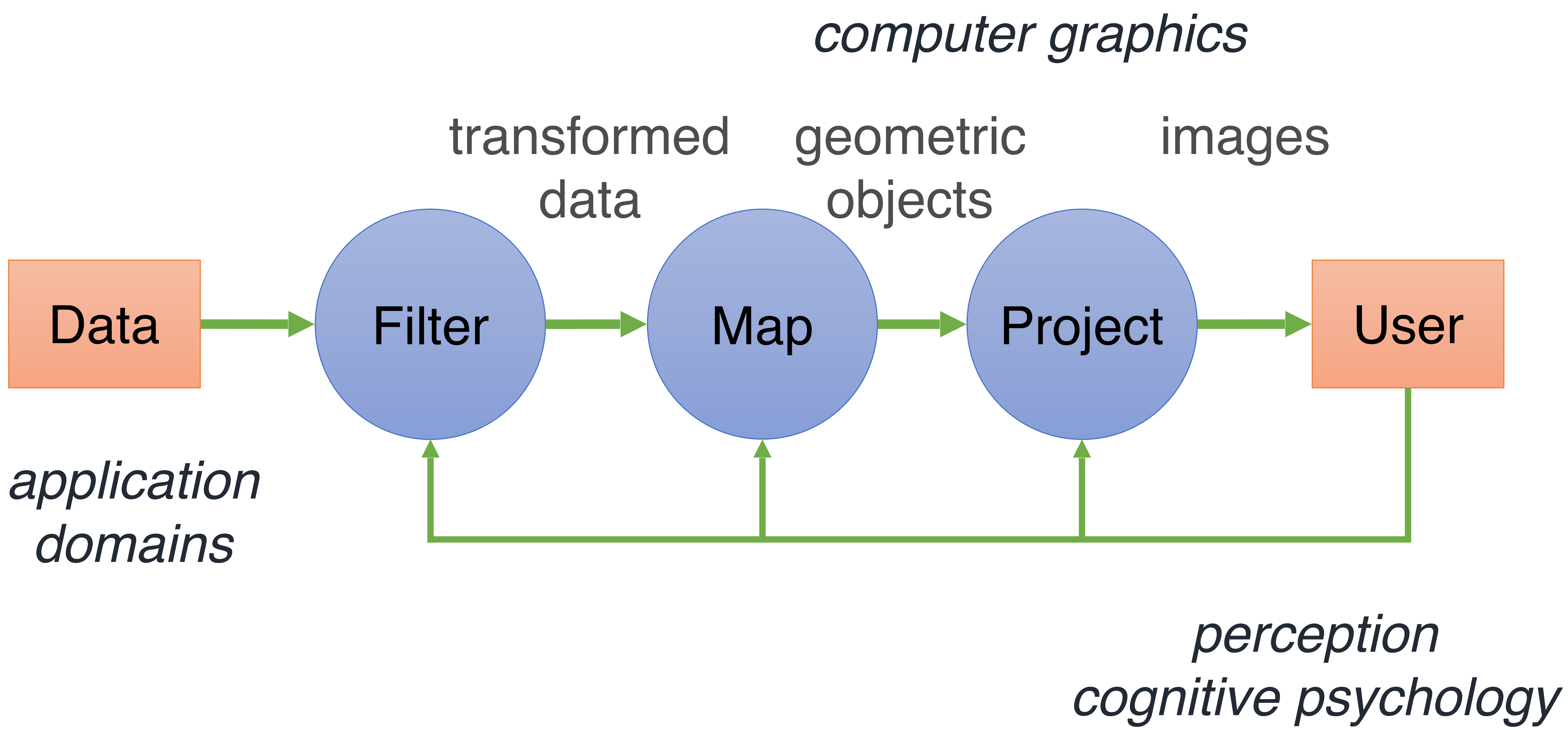
Visualization pipeline



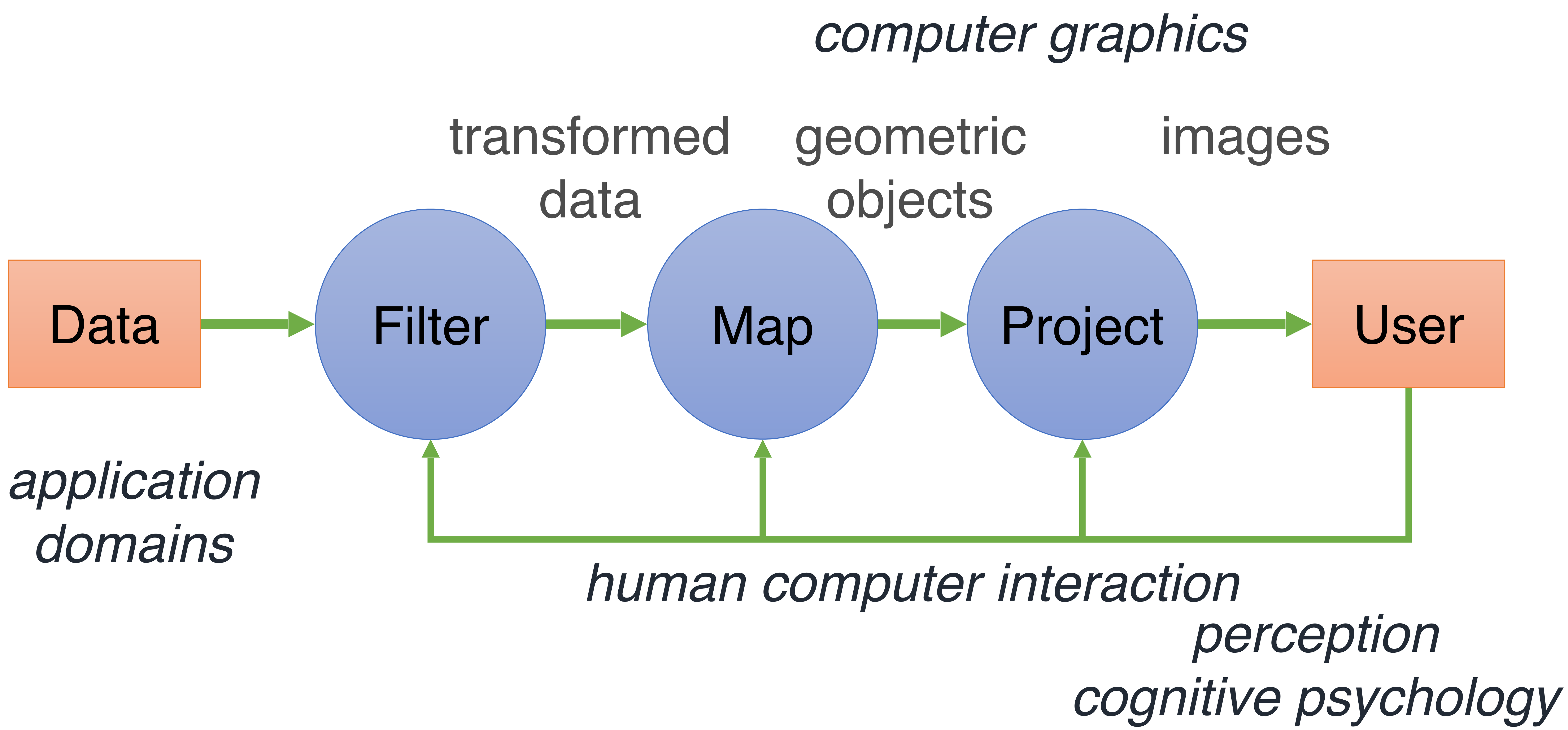
Visualization pipeline



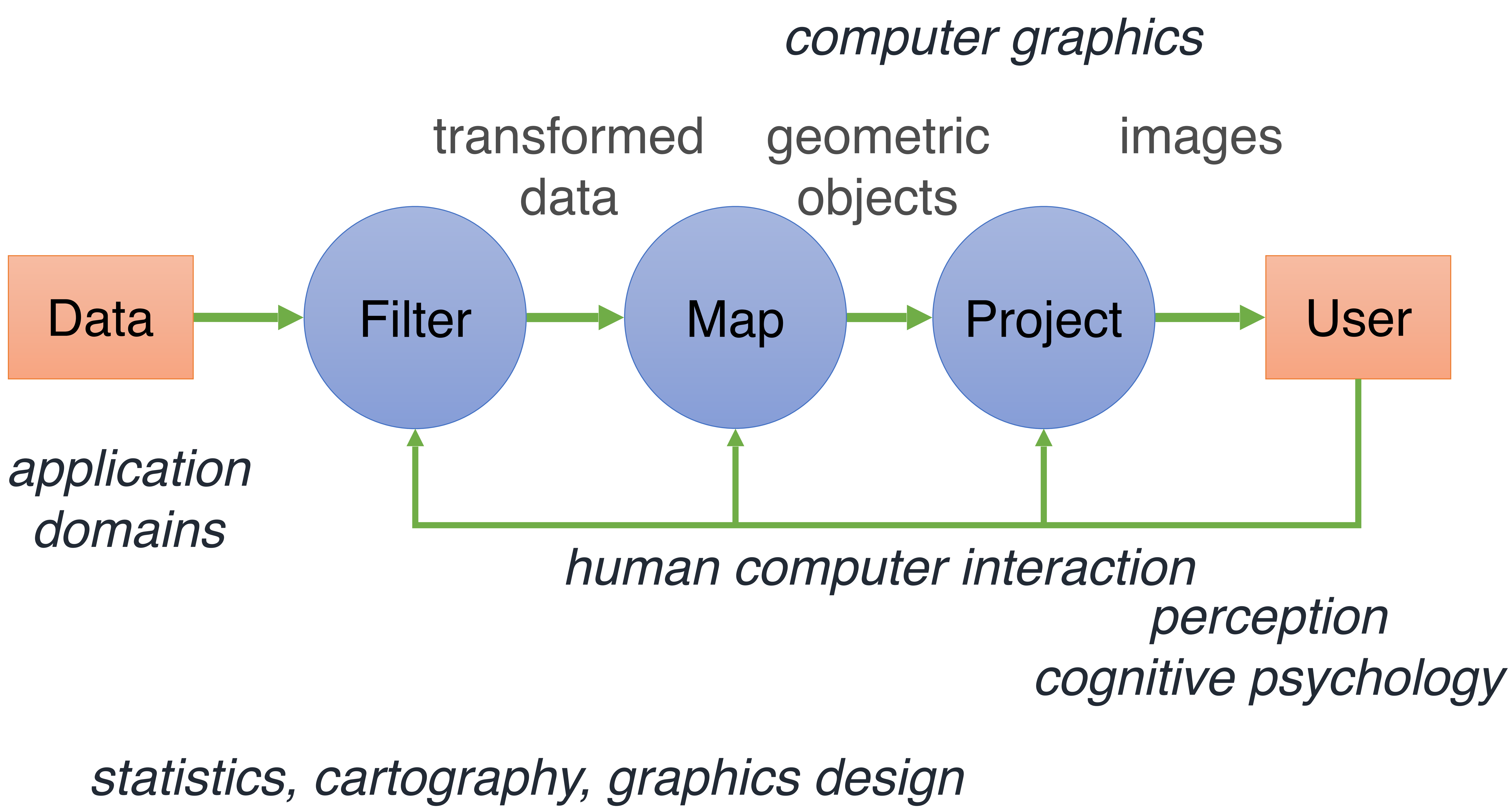
Visualization pipeline



Visualization pipeline

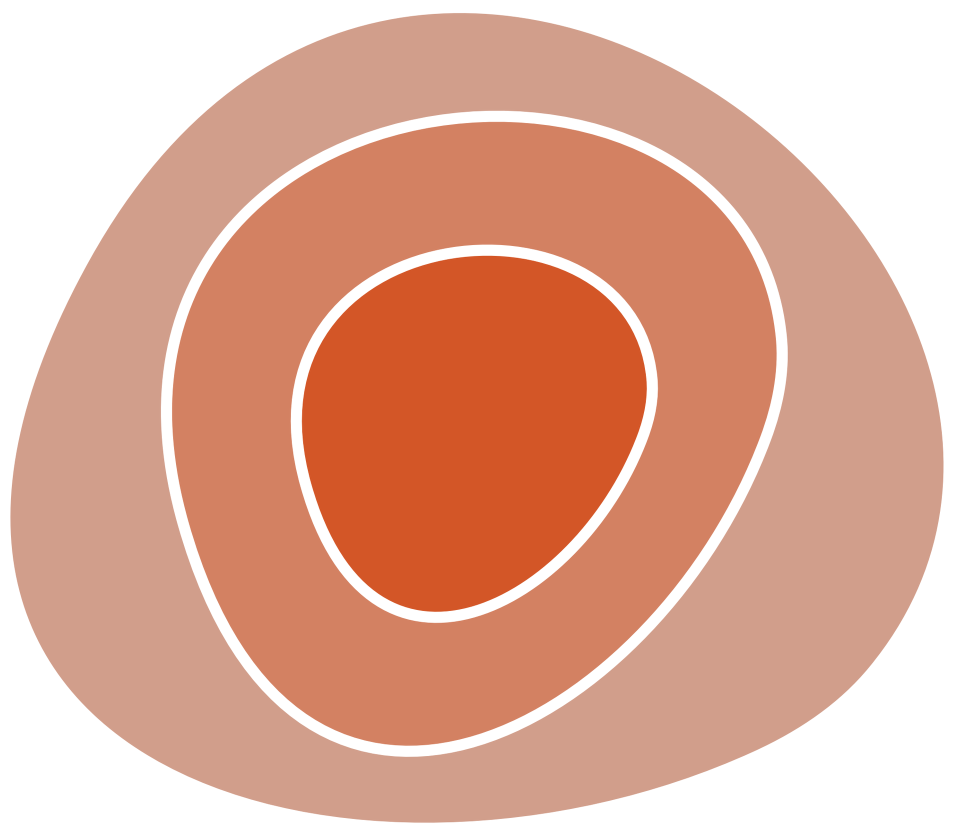


Visualization pipeline

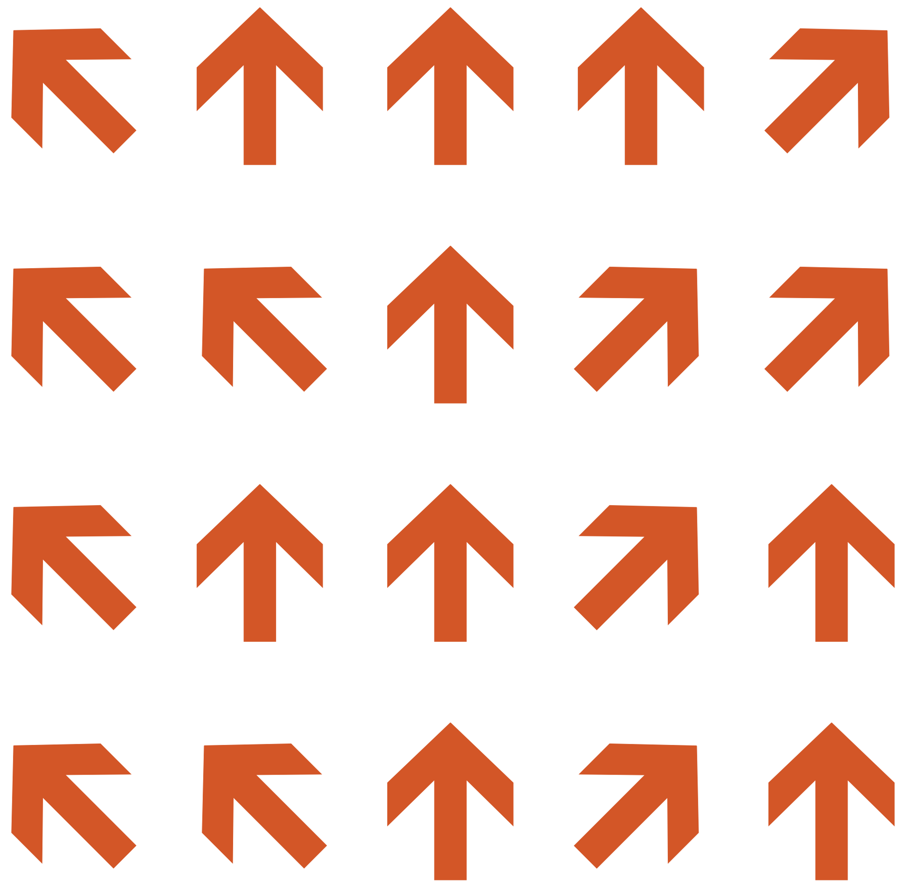


How: Visual encoding of spatial data

- Scalar fields (one value per cell)
  - isocontours
  - (direct) volume rendering

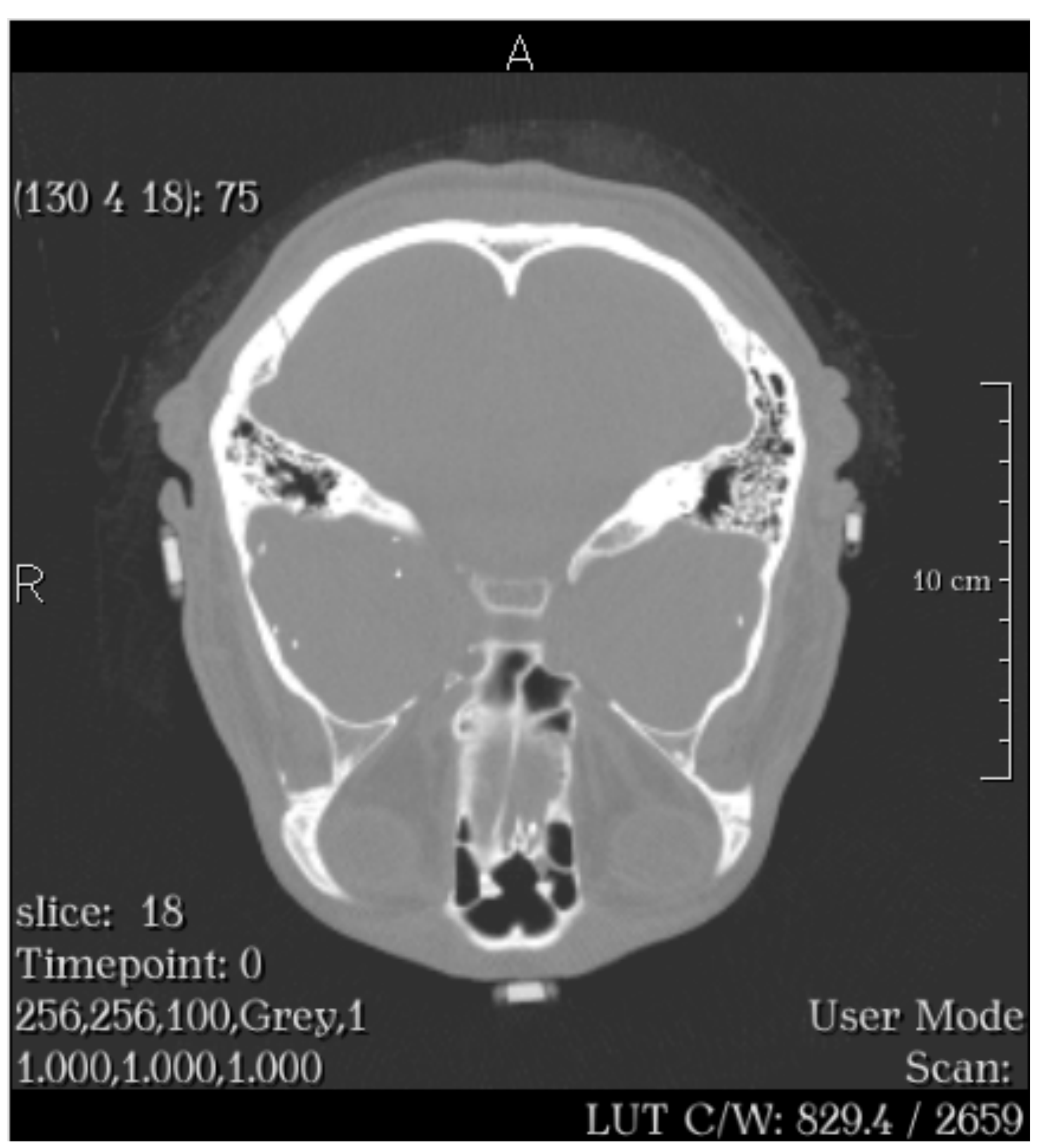


- Vector and tensor fields (many values per cell)

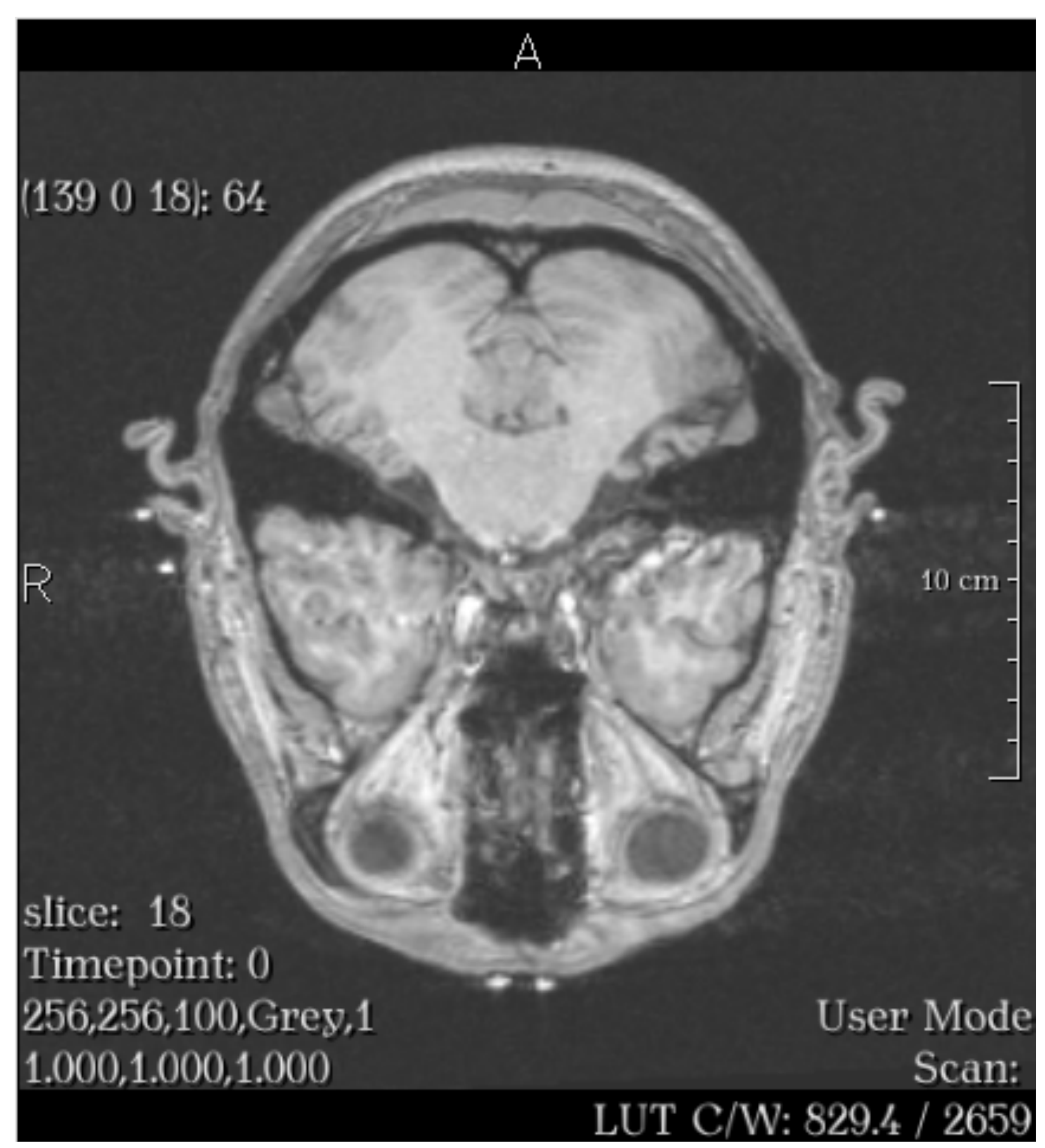


Volume data

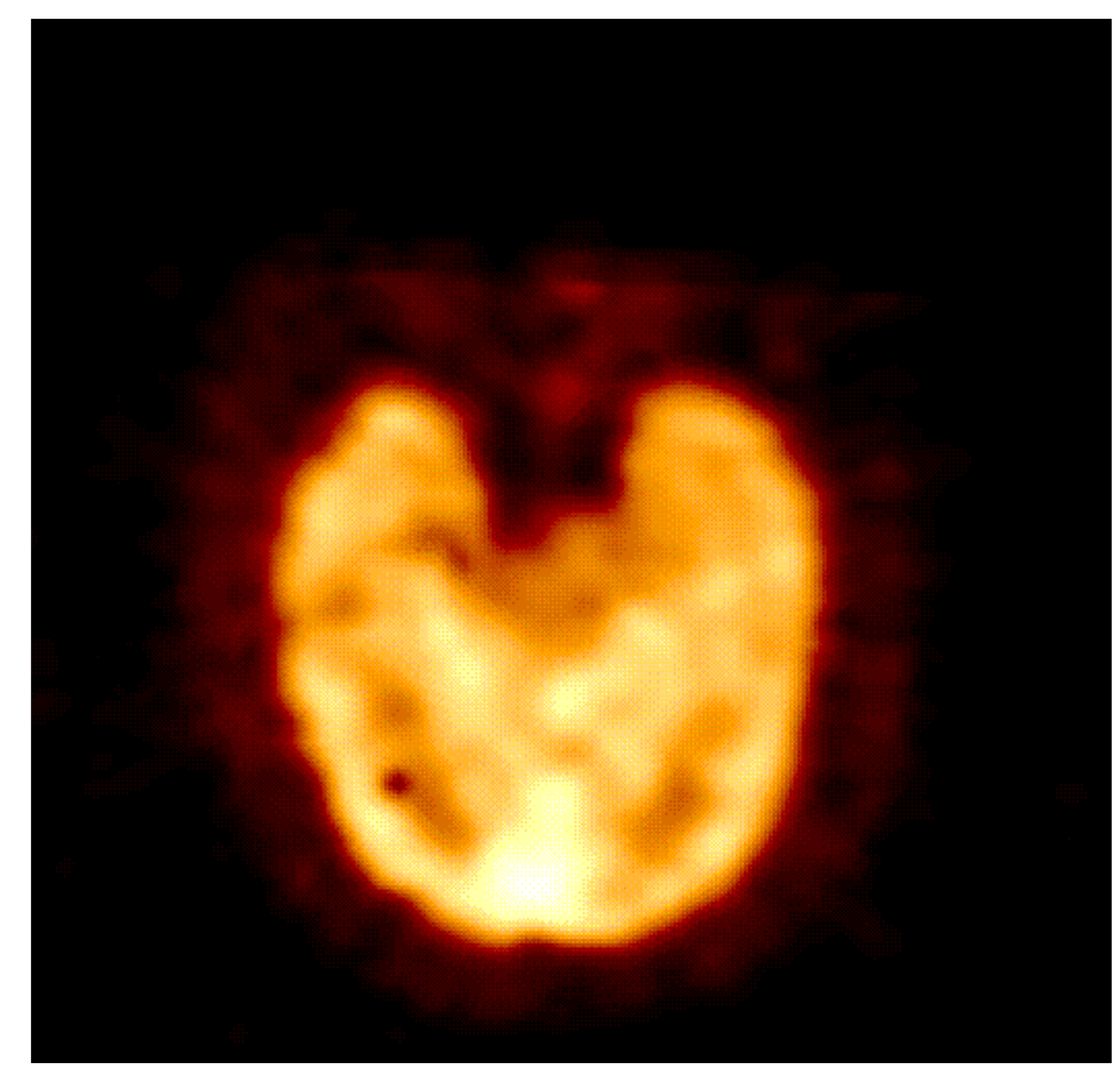
- Samples at regularly-spaced intervals
- Isotropic or anisotropic sampling
- Samples are called **voxels**



Computed tomography (CT)

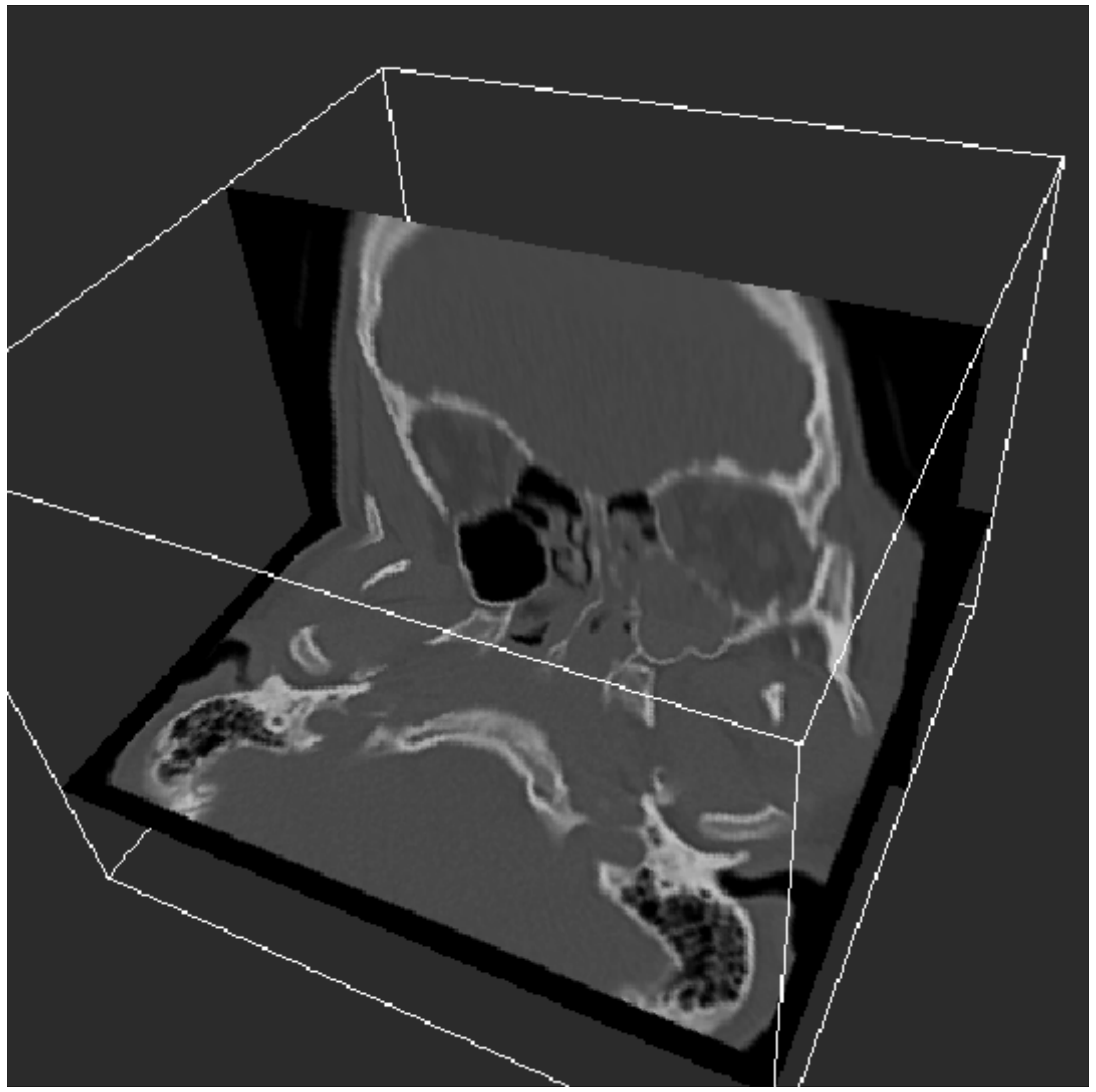


Magnetic resonance imaging (MRI)

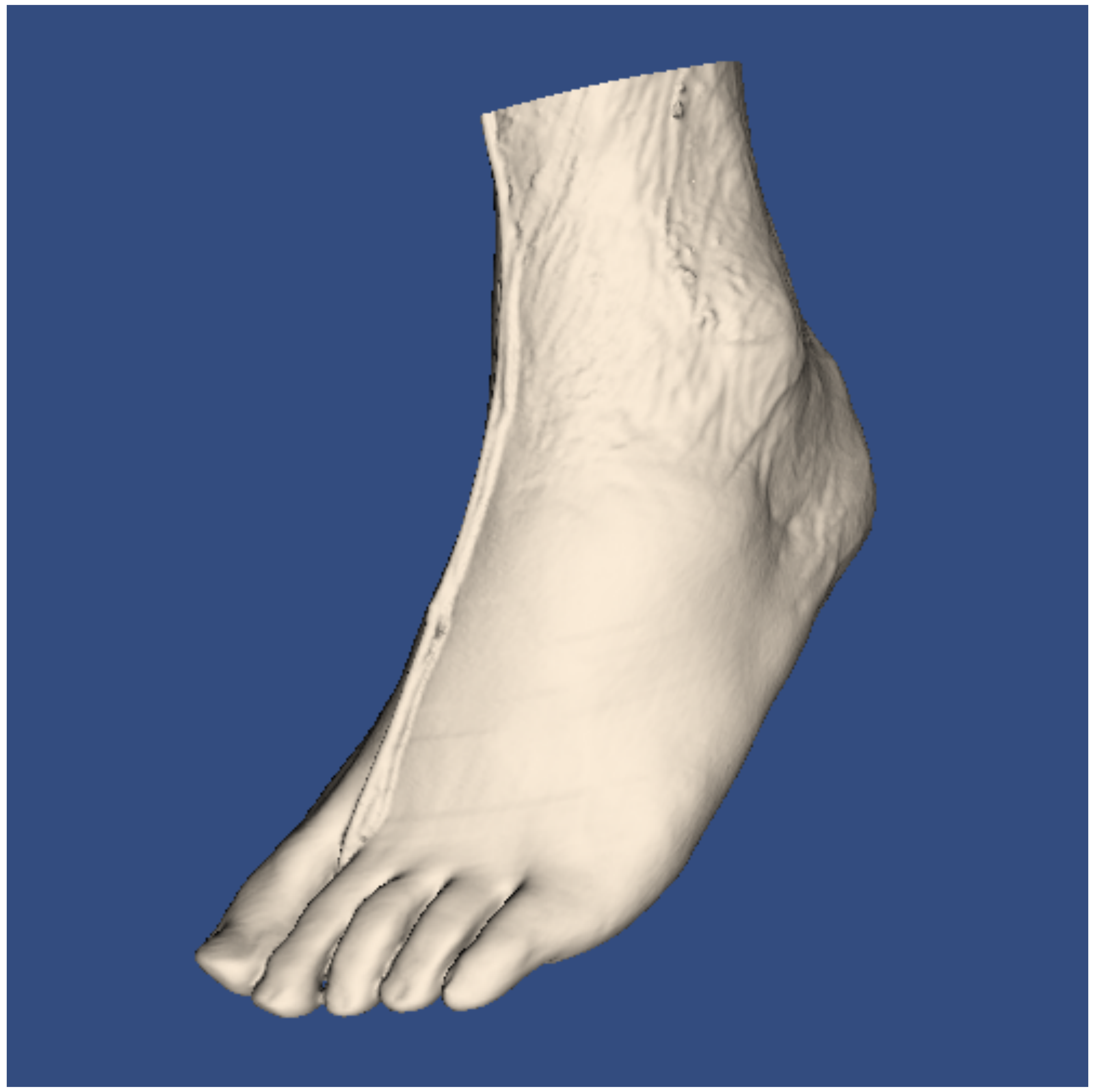


Positron emission tomography (PET)

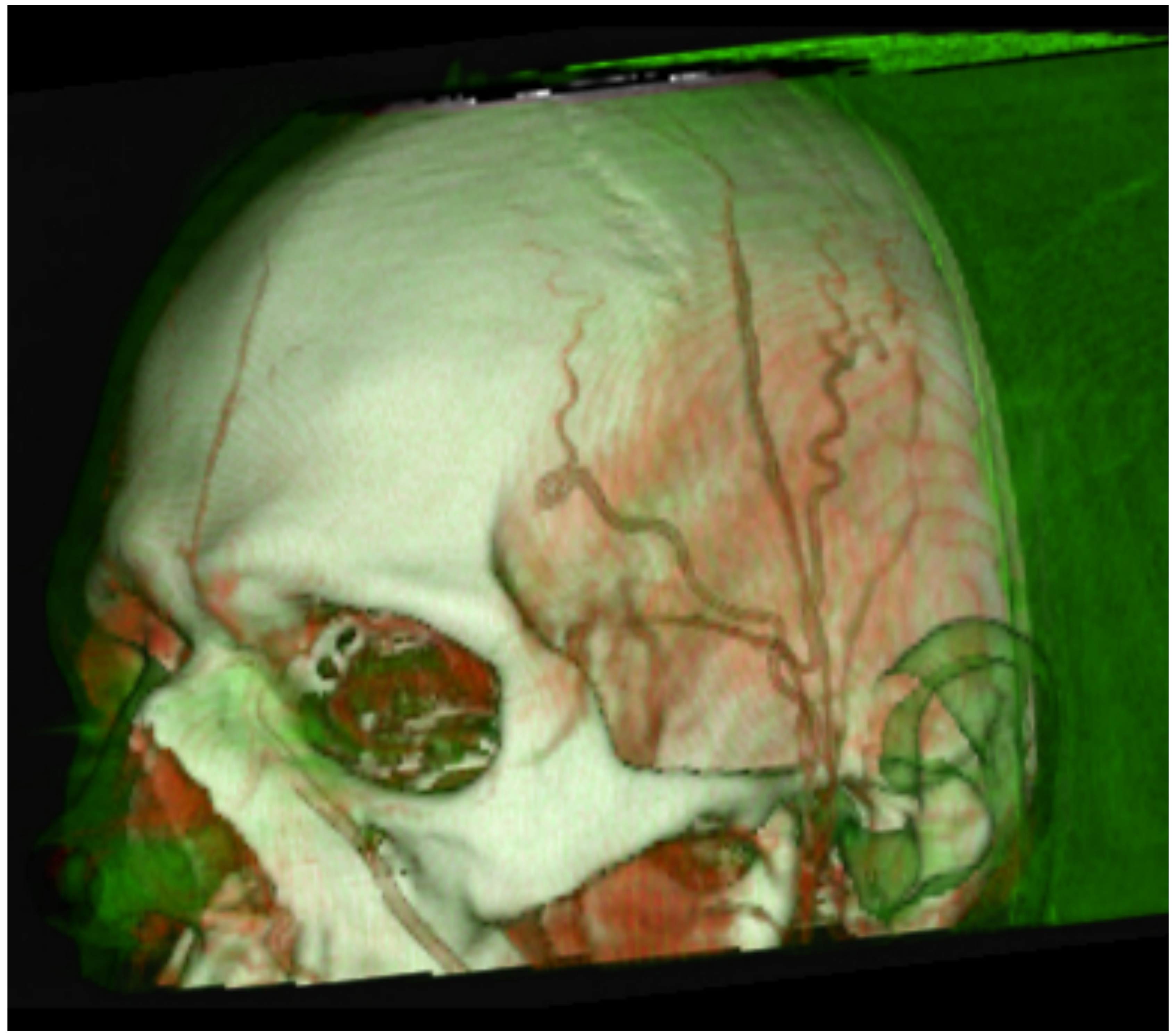
Volume rendering methods



Slice-by-slice

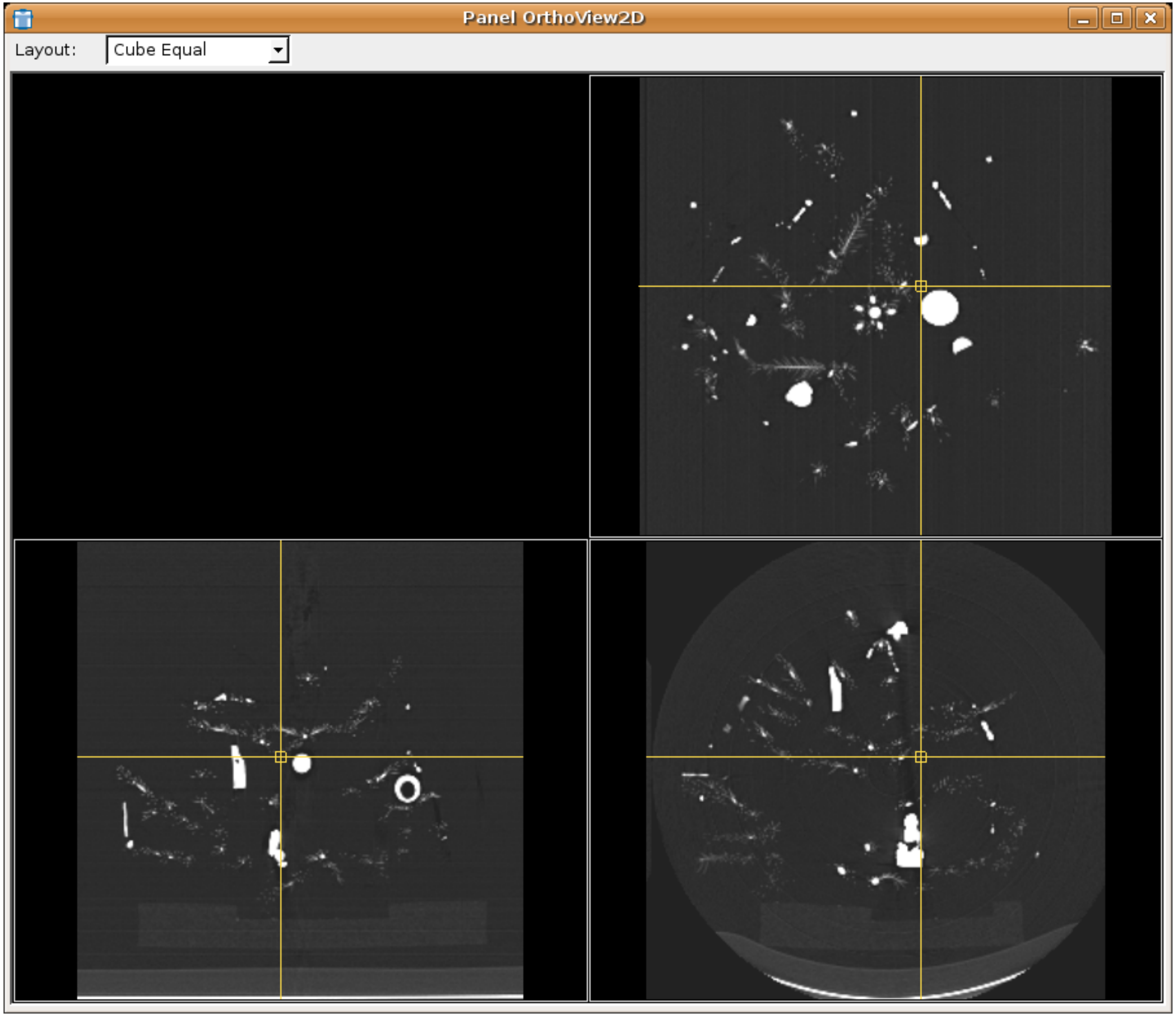


Isosurfaces



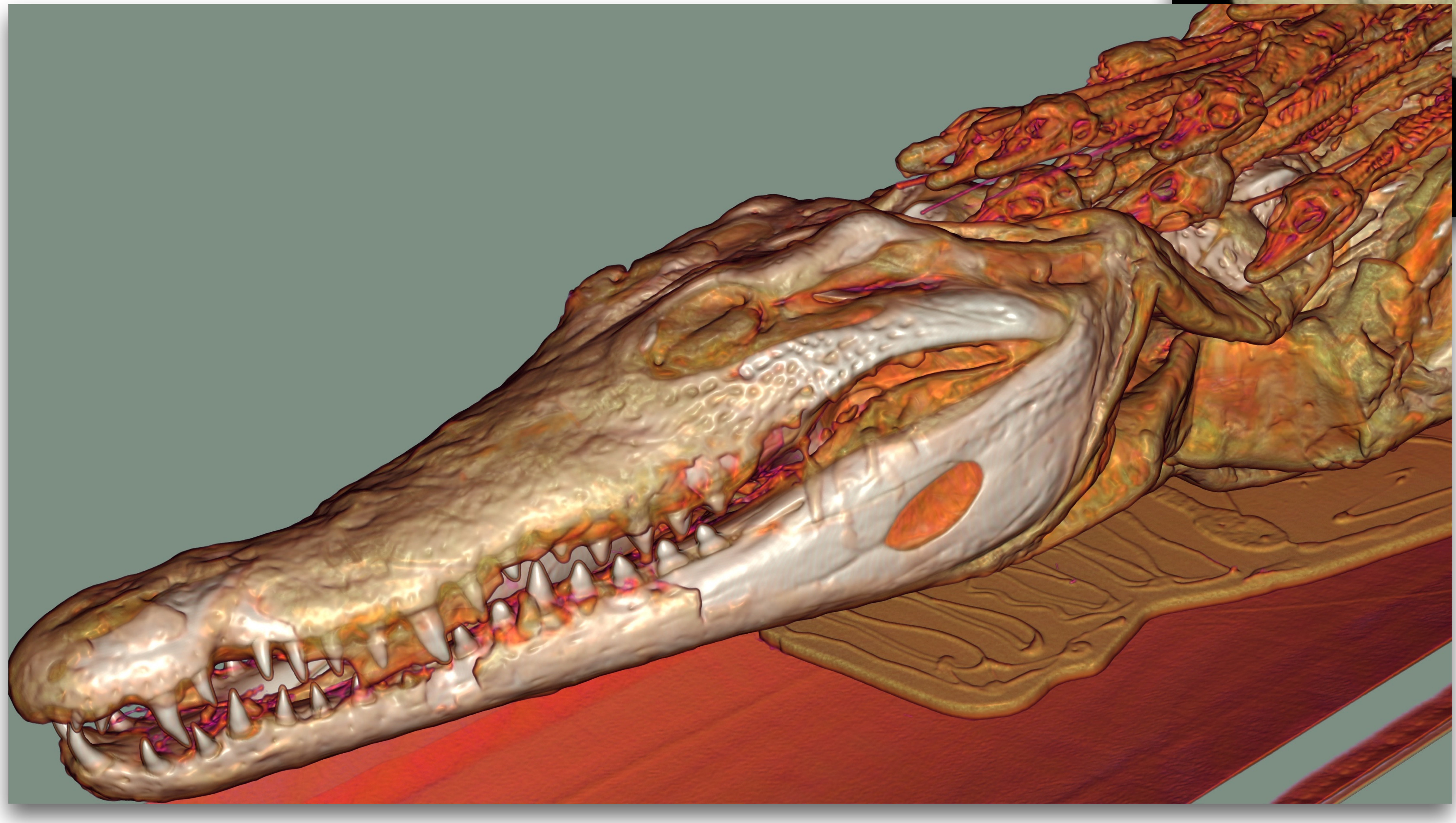
Direct volume rendering

Slice-by-slice: useful?



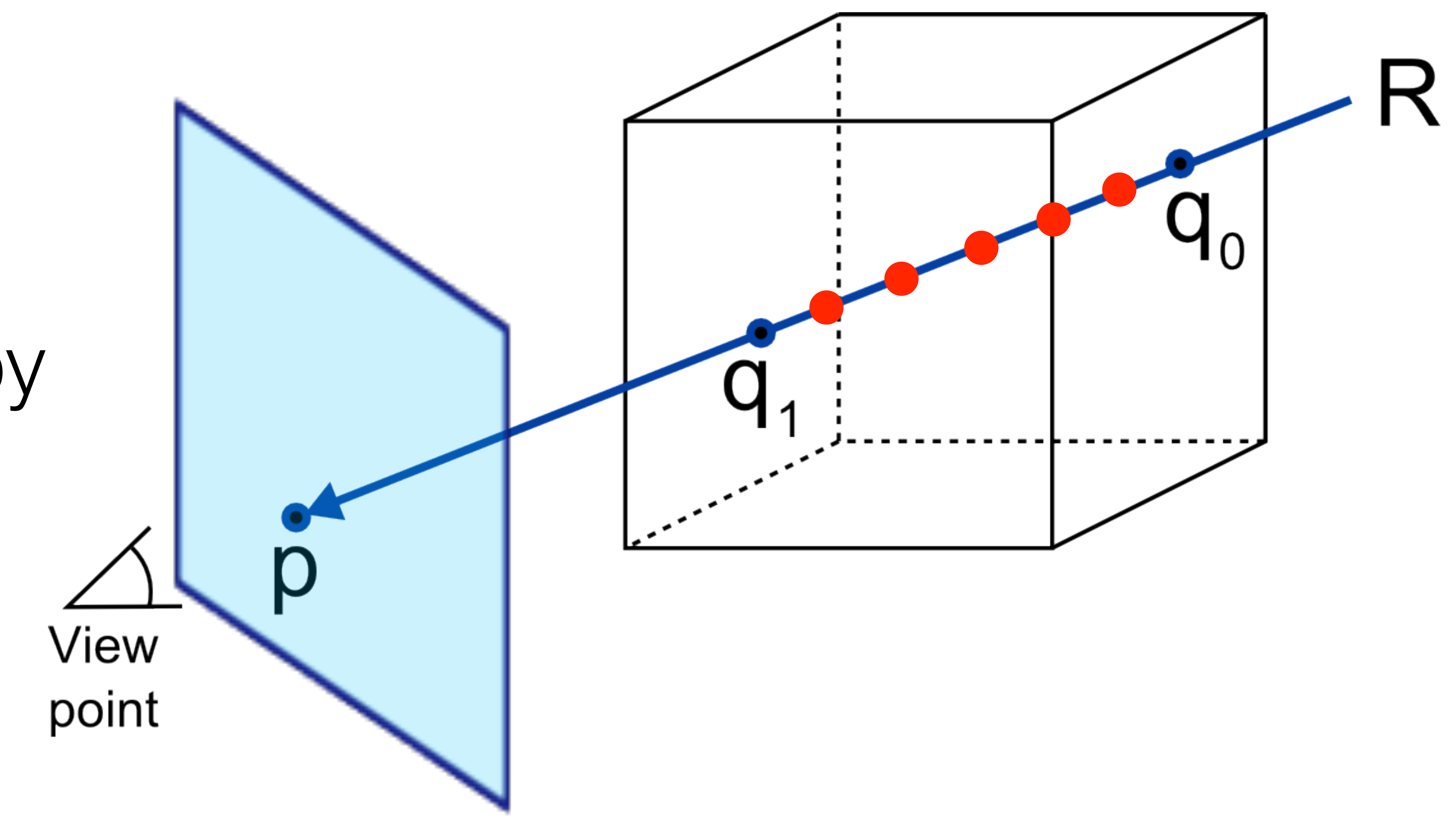
Direct volume rendering

- No derived geometry
- Scalar values
  - used directly (MIP)
  - mapped through a **transfer function** to obtain colors and opacities (DVR)



Direct volume rendering: ray casting

- For every pixel **p** in final image, cast ray **R** perpendicular to view plane
- Combine samples **q** on the ray by a ray function **F**



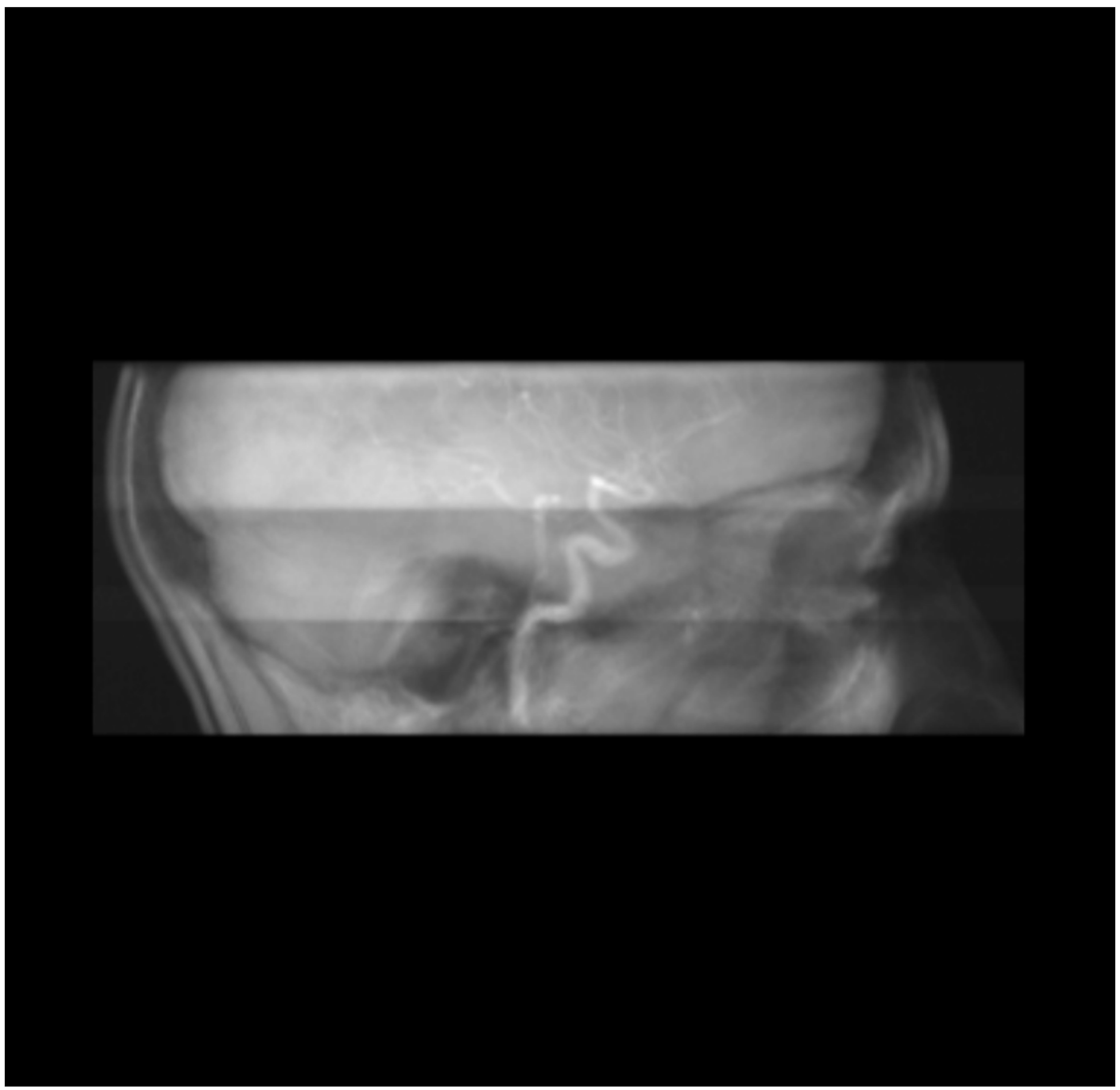
R parametrization $q_t = q_0 + t(q_1 - q_0) \quad t \in [0, 1]$

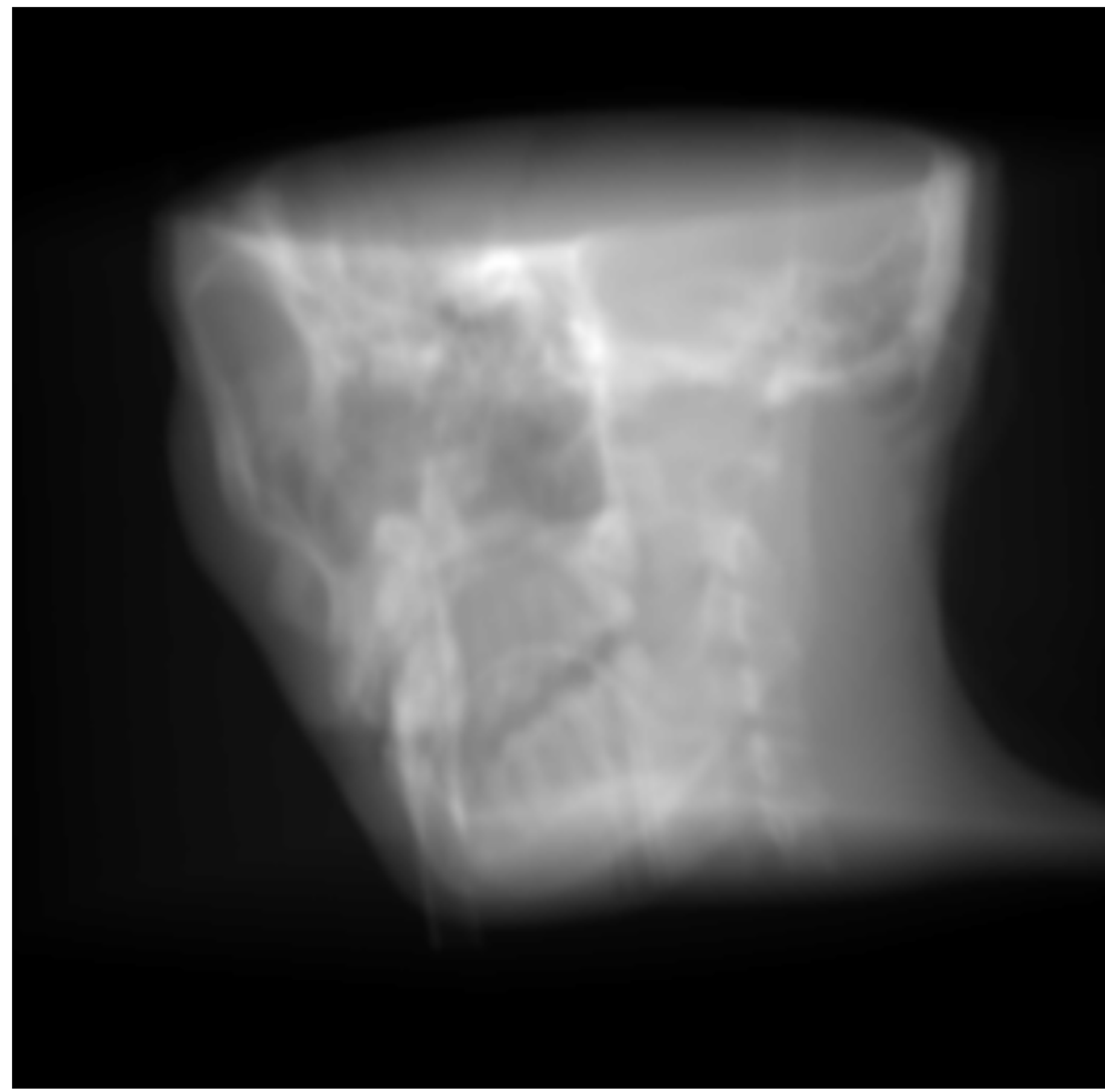
scalar values along R $s_t = f(q_t)$

pixel value in p $I(p) = F(s_t)$

X-ray projection

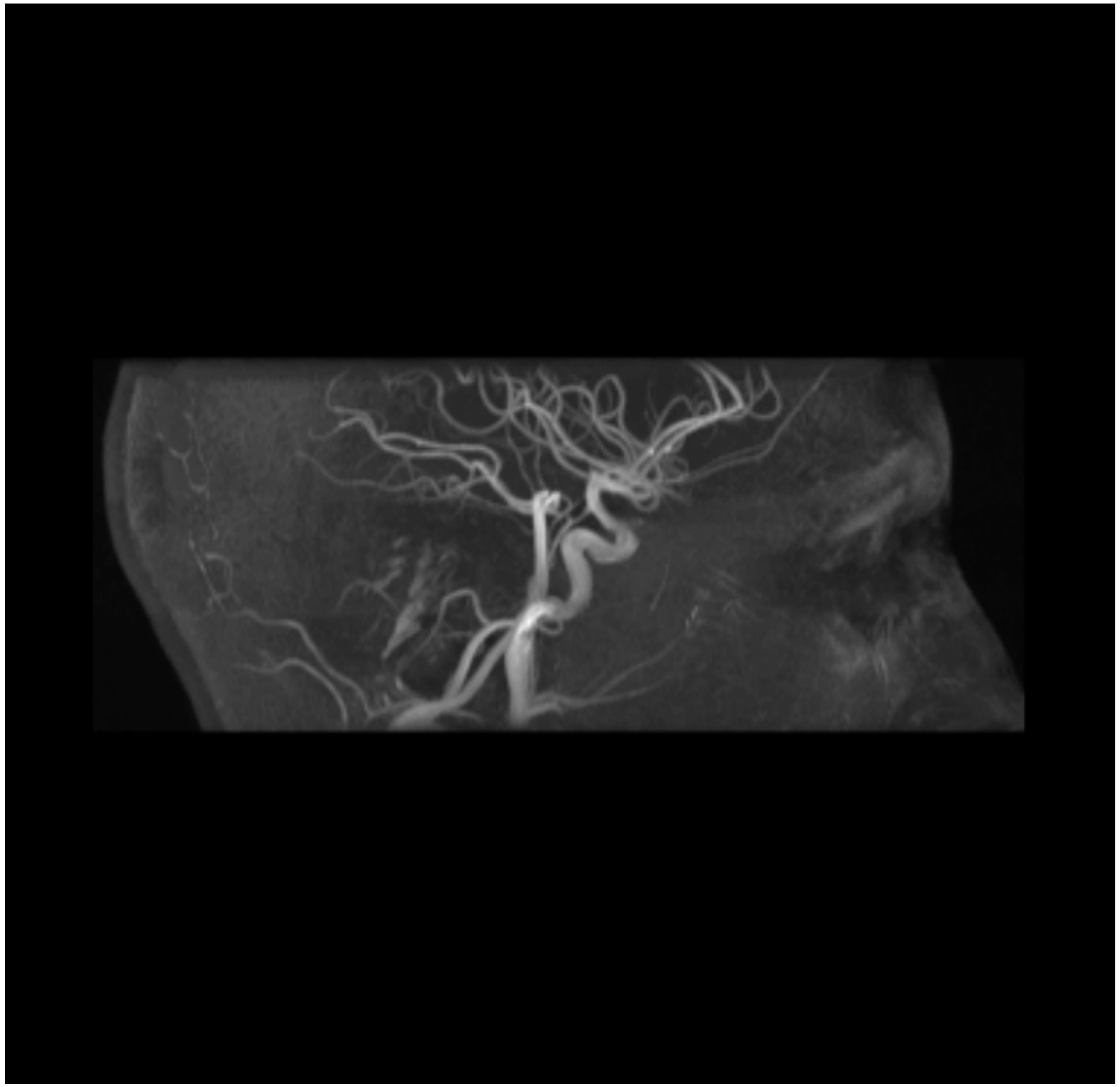
- Take for F summation operator: $I(p) = \sum_t s_t$

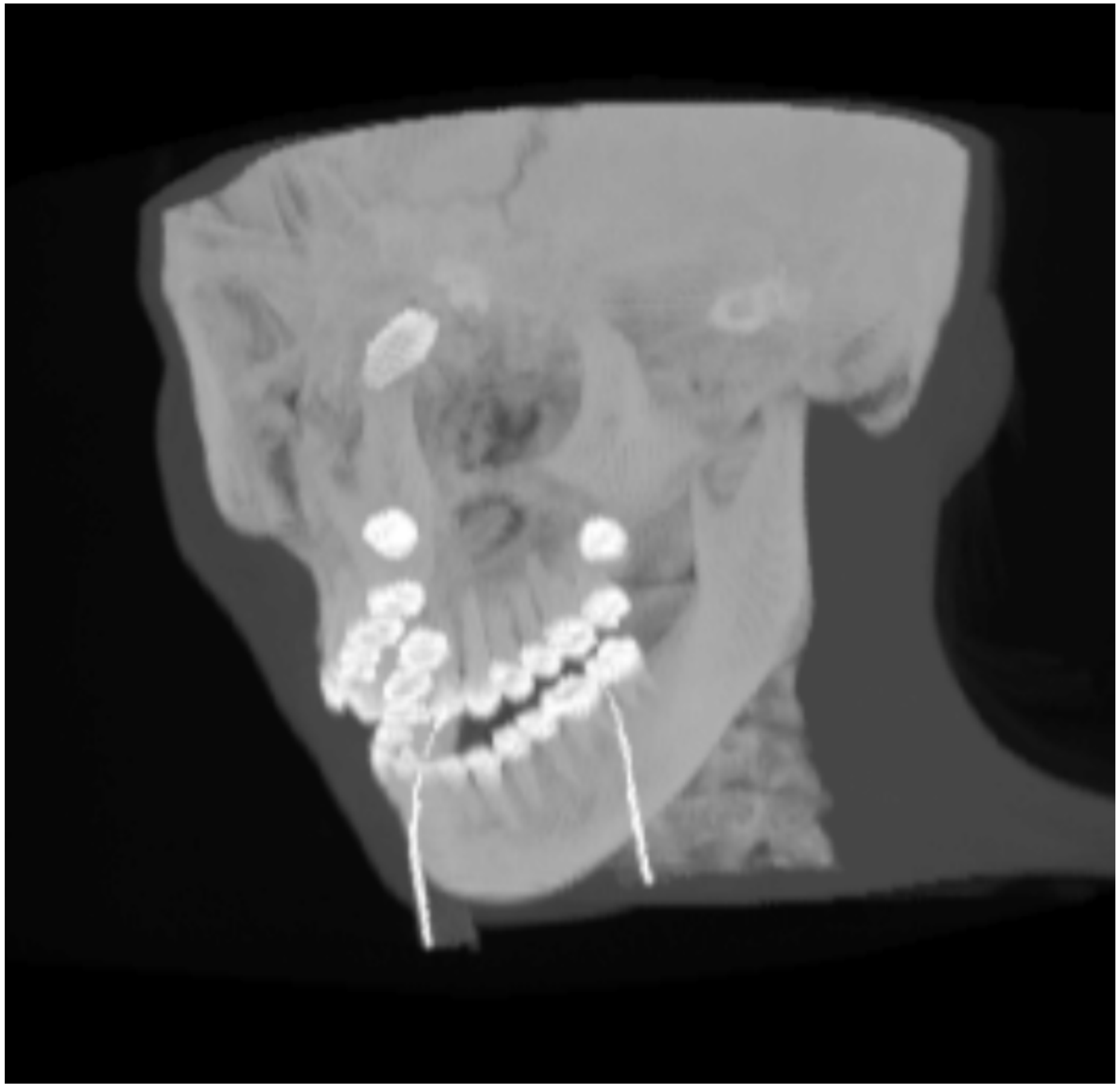




Maximum intensity projection

- Take for F maximum operator: $I(p) = \max_t s_t$





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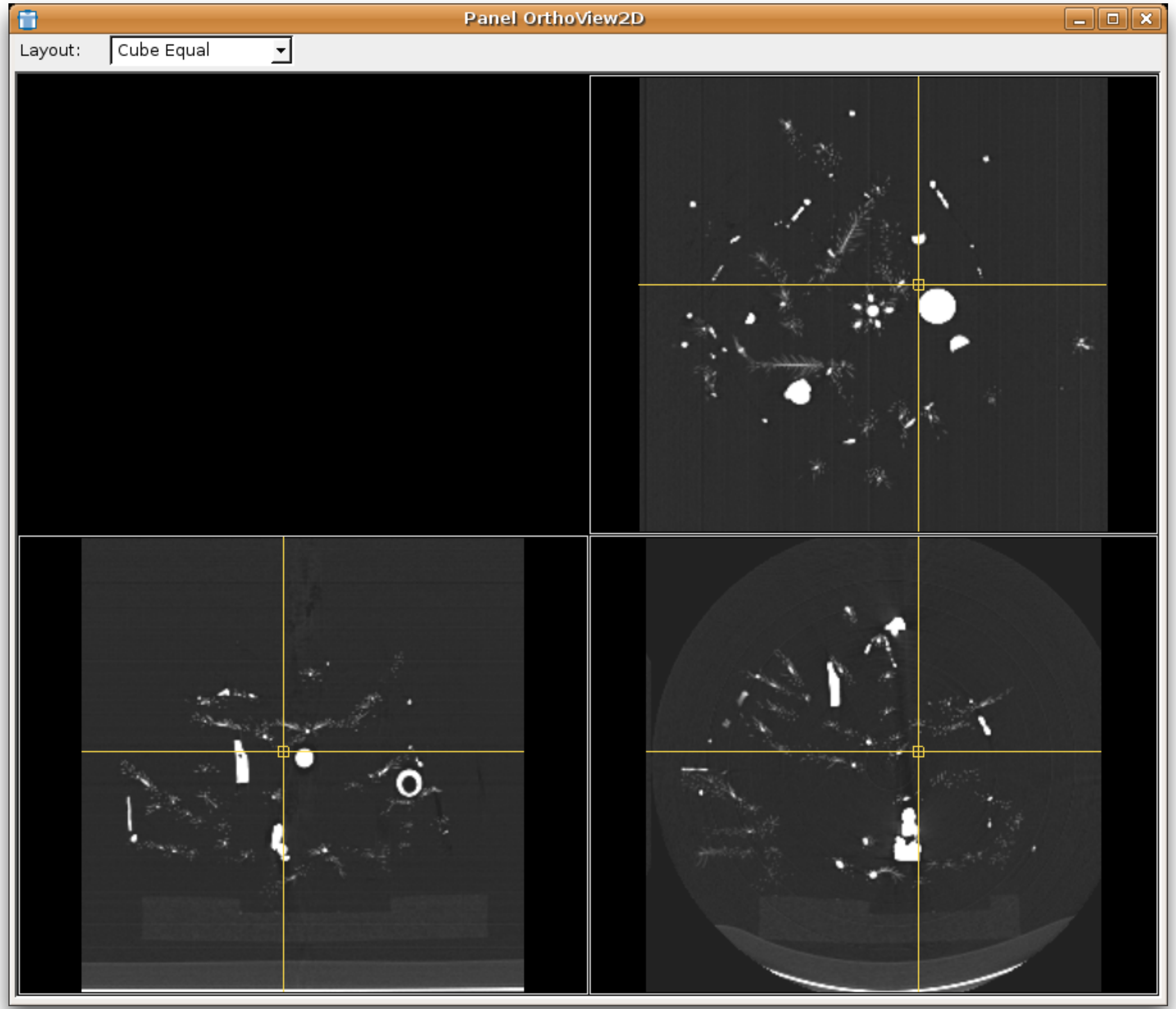
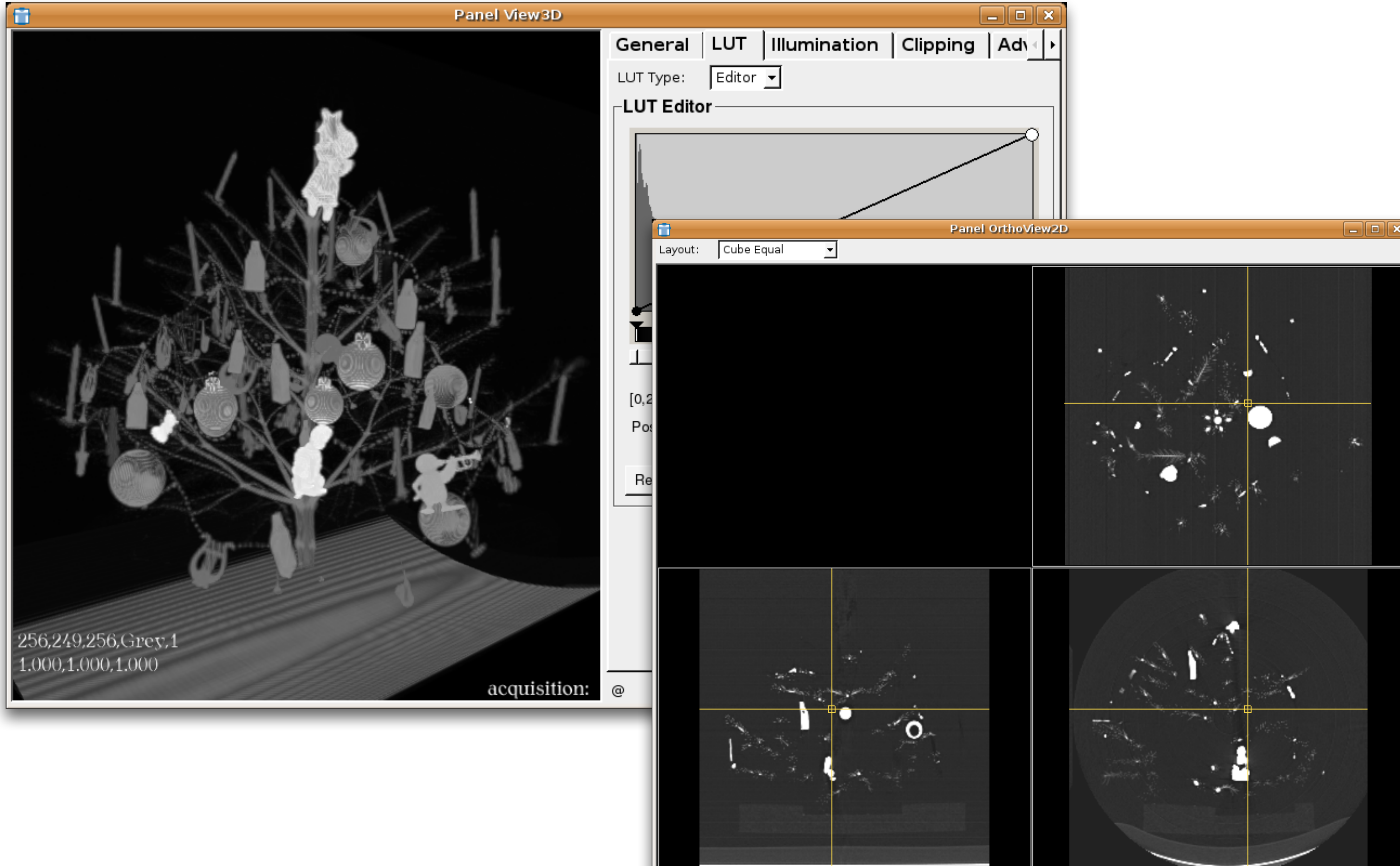
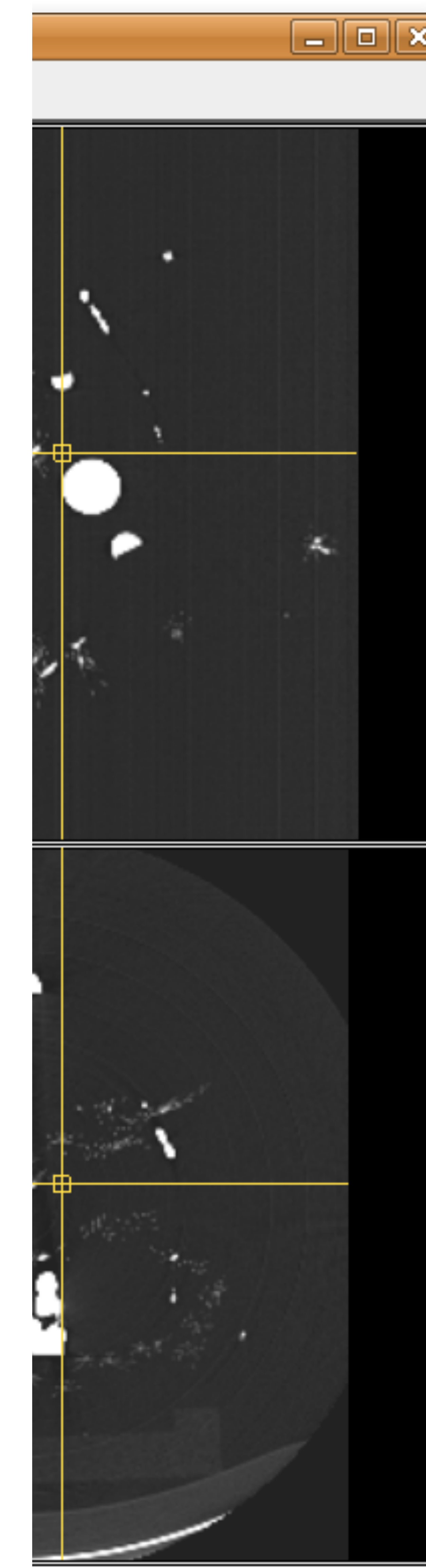
Dataset revisited

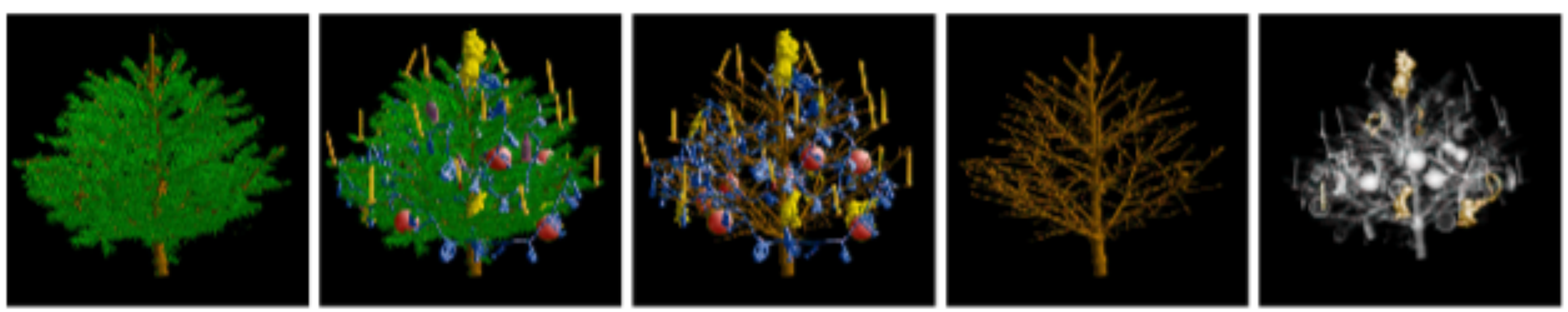


Dataset revisited



Dataset revisited





Christmas Tree Case Study: Computed Tomography as a Tool for Mastering Complex Real World Objects with Applications in Computer Graphics

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Balázs Csébfalvi[‖] Jiří Hladůvka[‖] Dominik Fleischmann[§] Michael Knapp[‖] Rainer Wegenkittl[†]
Petr Felkel[‡] Stefan Röttger[¶] Stefan Guthe[**] Werner Purgathofer[‖] Meister Eduard Gröller[‖]

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Figure 1: A short story: Before Christmas – the 25th – left for holidays – the sad end – Christmas tree in heaven.

Abstract

We report on using computed tomography (CT) as a model acquisition tool for complex objects in computer graphics. Unlike other modeling and scanning techniques the complexity of the object is irrelevant in CT, which naturally enables to model objects with, for example, concavities, holes, twists or fine surface details. Once the data is scanned, one can apply post-processing techniques for data enhancement, modification or presentation. For demonstration purposes we chose to scan a Christmas tree which exhibits high complexity which is difficult or even impossible to handle with other techniques. However, care has to be taken to achieve good scanning results with CT. Further, we illustrate post-processing by means of

1 Introduction

In computer art, one is often faced with the task to digitize real world objects for further processing with various computer graphics tools. The commonly used methods like range scanning suffer from certain limitations since only information of the visible surfaces of objects is provided. Non-convex surfaces, an inherent property of complex objects, often cause difficulties or even cannot be handled at all. Similar arguments hold for taking a set of photographs from different viewpoints to be used for image based rendering.

With procedural modeling of existing physical objects it is difficult to come up with an accurate description of the real world object. Furthermore it requires special effort to get a physically

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Reading this week

Tutorial

How to Read a Visualization Research Paper: Extracting the Essentials

Robert S. Laramee ▪ *Swansea University*

Visualization students or researchers investigating an unfamiliar topic often review the scientific literature about that subject. Reading the many scientific papers and capturing their essential information is a challenge. However, remembering all the details isn't necessary. Several simple guidelines can help you extract the most important information from visualization research papers.

When pursuing an unfamiliar research direction, a researcher, possibly a PhD student, must undertake a literature search. This search aims to discover what research has already been carried out in a given field (solved problems) and what research hasn't (unsolved problems).

However, in visualization and computer graphics, reading a refereed conference or journal paper can be challenging owing to its high level of specialization, complexity, and detail. Such papers often present a detailed mathematical framework accompanied by algorithms and data structures to carry them out and are usually written by (or with the aid of) experts in the field with many years' experience. This complexity comes as no great surprise because a single paper is often the result of many (combined) person-years of work.

Furthermore, a PhD student or a researcher starting in a new direction must wade through tial information when reading a visualization (or computer graphics) paper. In particular, I describe how to read the paper to perform a literature review—for example, to write a Eurographics STAR (state-of-the-art report). Such a report is a helpful way to get an overview of published research in a subfield of visualization and computer graphics.

This article builds on my experience in both writing literature reviews[2–9] and teaching in the classroom. I've given these guidelines for undergraduate, master's, and PhD students taking my Data Visualization class, as part of an assignment requiring them to summarize a visualization paper, extracting and capturing the most important concepts and information. This is the first time many of the students have had to do this. These guidelines have demonstrated themselves useful for this task. They can be given out directly in the classroom and discussed. They've also formed the basis for several successful literature reviews as part of students' PhD work.[2–6,8]

Concept versus Implementation

First, it's important to understand the difference between a concept and its implementation. Looking up the meanings of "concept" and "implemen-