Feature Detection in Data Analysis

University of Houston, Spring 2013

Instructor: Guoning Chen

Course Information

- **Location:** SEC 201
- **Time:** 10am~11:30am Tuesday and Thursday
- **Office Hours**: 11:30am~12:30pm Tuesday and Thursday, or by appointment.
- **Office:** PGH 566
- **Email:** chengu@cs.uh.edu
- **Course webpage**: http://www2.cs.uh.edu/~chengu/Teaching/Spring2013/Analysis_Spring2013.html
- **TA:** Cheng Xiao

Course Information

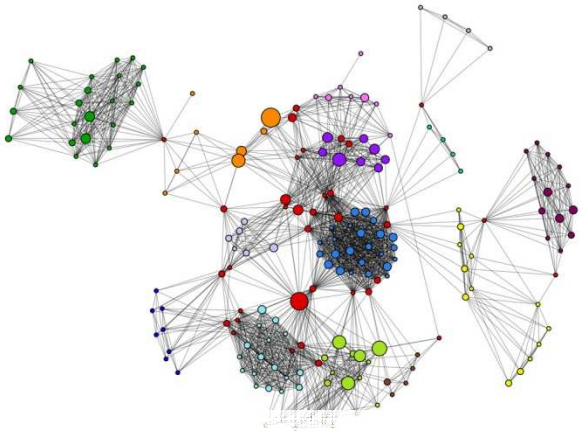
- **Prerequisites**:
  - Algorithms and data structures
  - Knowledge and experience in programming (we will use C/C++, other languages are possible, please talk to me)
  - Computer graphics and OpenGL (will provide a review in next lecture), or other library with graphics functionality
  - Mathematics (as a start you will need linear algebra, numerical analysis, and calculus)

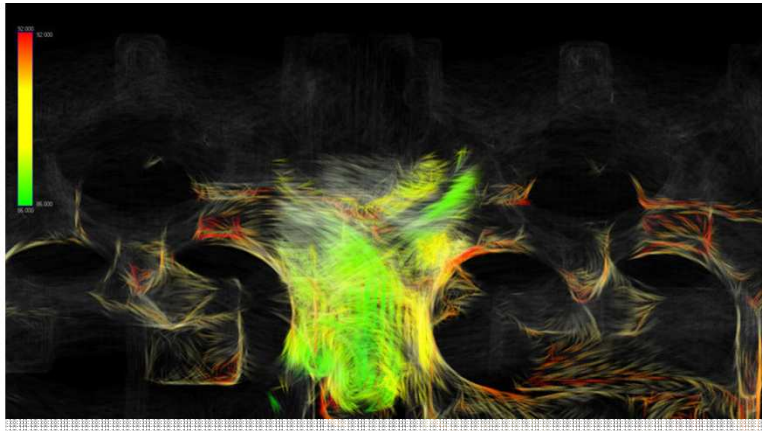
- **Textbook:** (recommended)
  - Topology-Based Methods in Data Analysis and Visualization: Theory, Algorithms, and Applications (Mathematics and Visualization) II, R. Peikert, H. Hauser, H. Carr, and R. Fuchs (Eds), Springer, 2012.
  - Topology-Based Methods in Data Analysis and Visualization: Theory, Algorithms, and Applications (Mathematics and Visualization), V. Pascucci, X. Tricoche, H. Hagen, and J. Tierny (Eds), Springer, 2010.
  - Visualization and Mathematics III (Mathematics and Visualization) (v.3) by Hans-Christian Hege and Konrad Polthier (Aug 13, 2003), Springer
  - Topology-Based Methods in Visualization II (Mathematics and Visualization) (v.2) by Hans-Christian Hege, Konrad Polthier and Gerik Scheuermann (Dec 18,2008), Springer.

Course Information

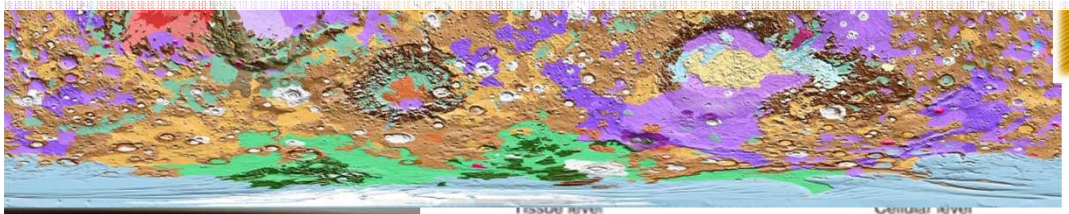
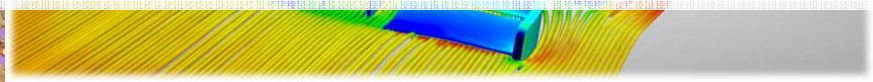
- **Grading:** 3 assignments (50%) + 1 final project and presentation (40%) + course participation (10%)
- **Late Policy**: Late assignments will be marked off 20% for each weekday that it is late.
- **Academic Dishonesty:** Do your own work! No code copy!

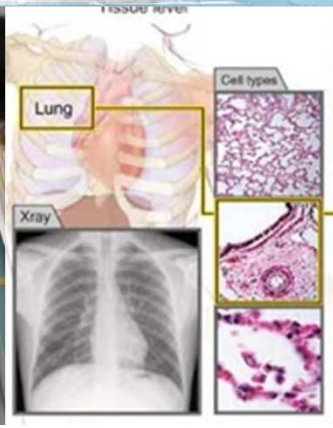
Background

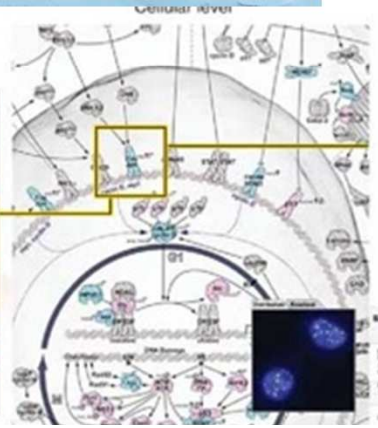
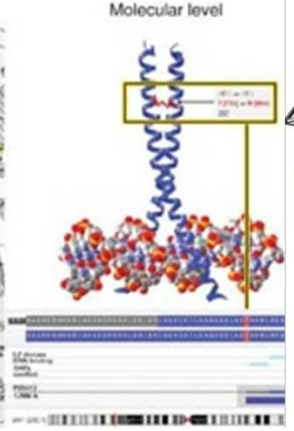


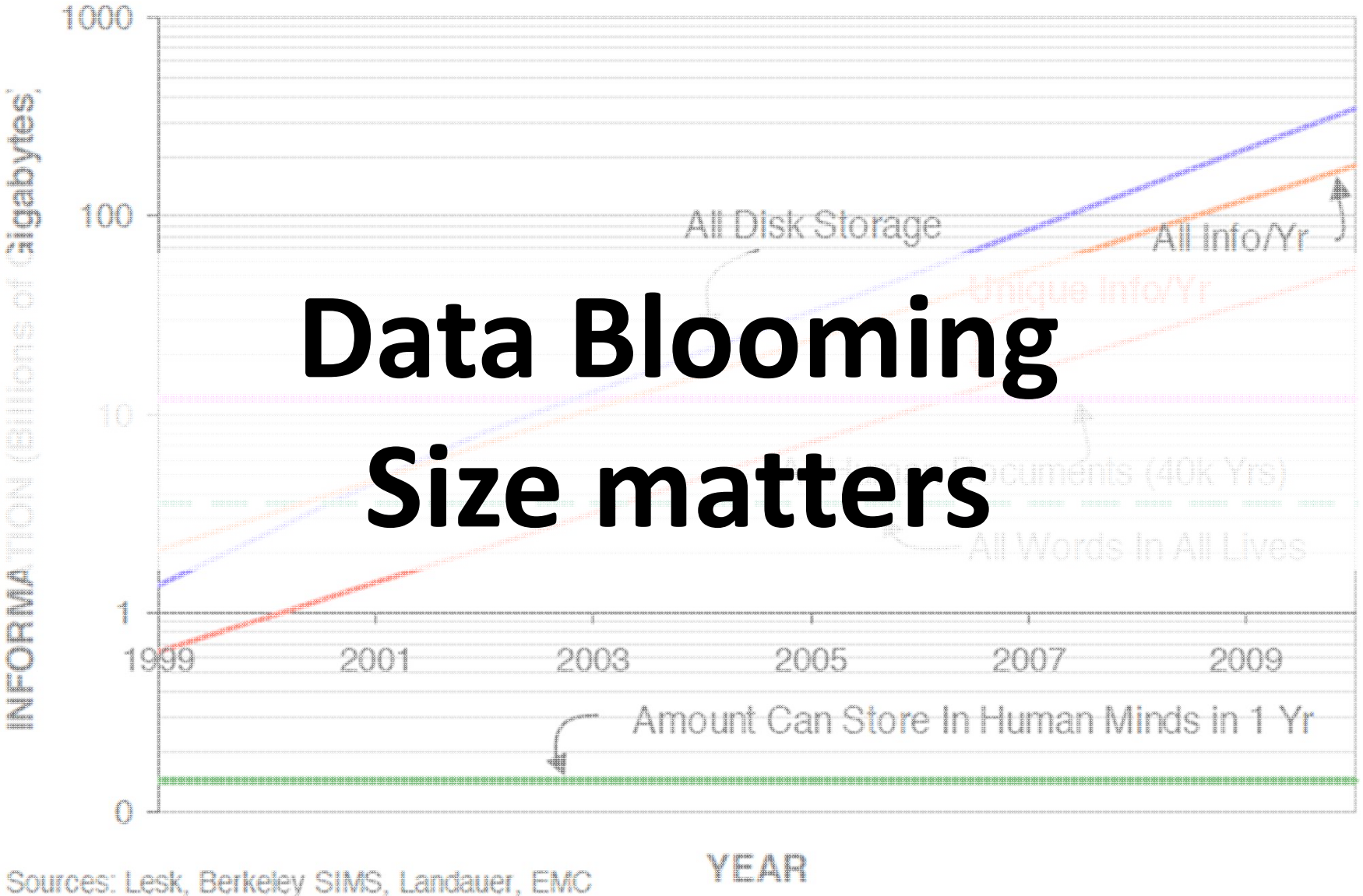


Data is generated everywhere



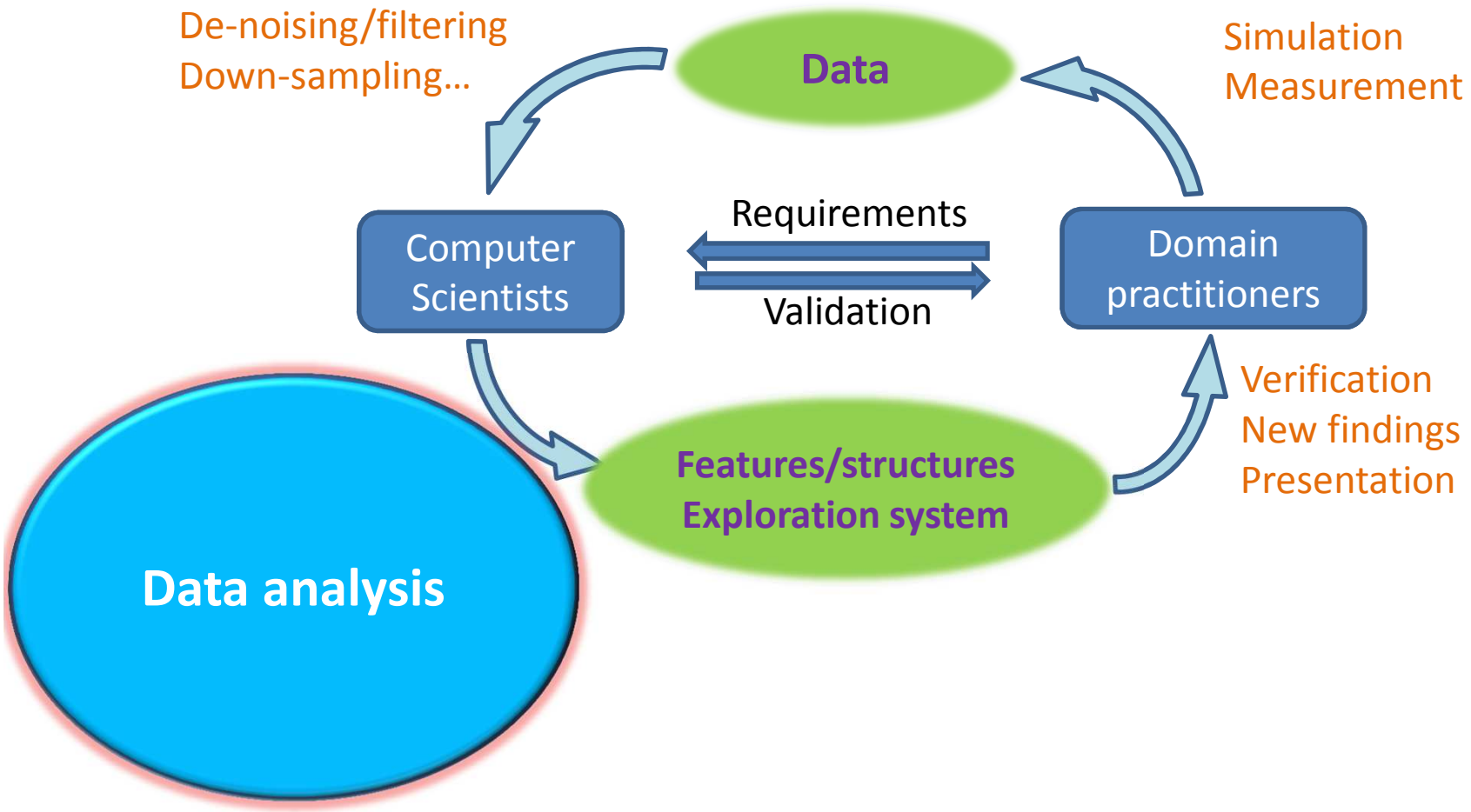





Data Blooming
Size matters

Sources: Lesk, Berkeley SIMS, Landauer, EMC

Data Analysis is important!



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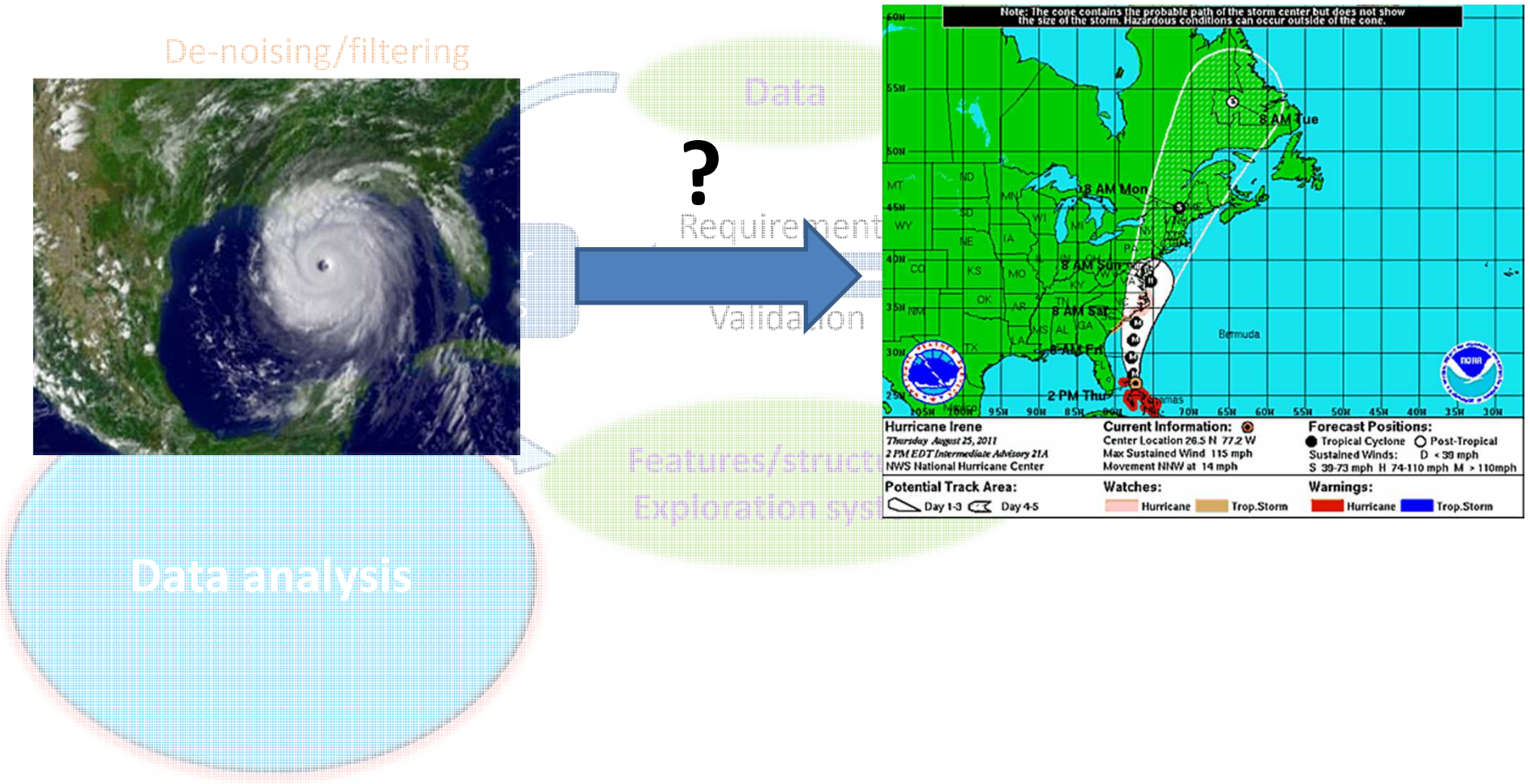

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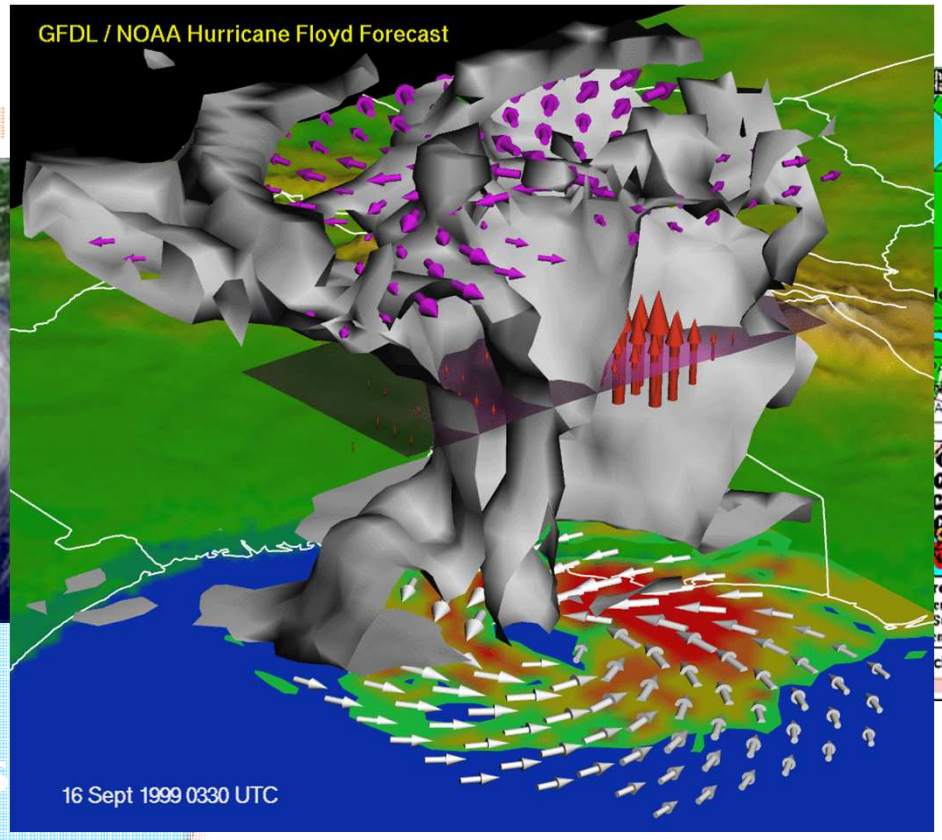

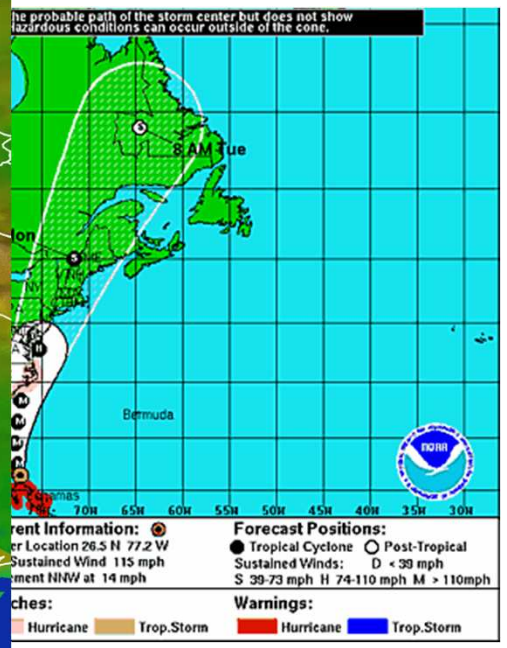

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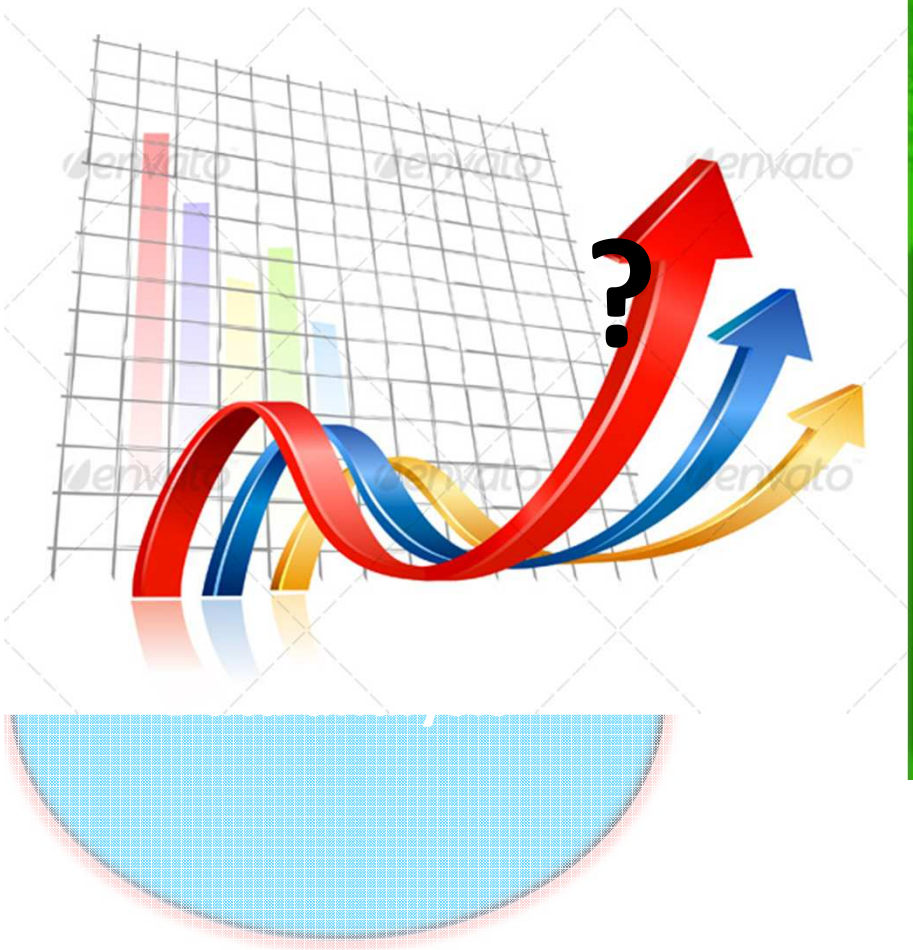

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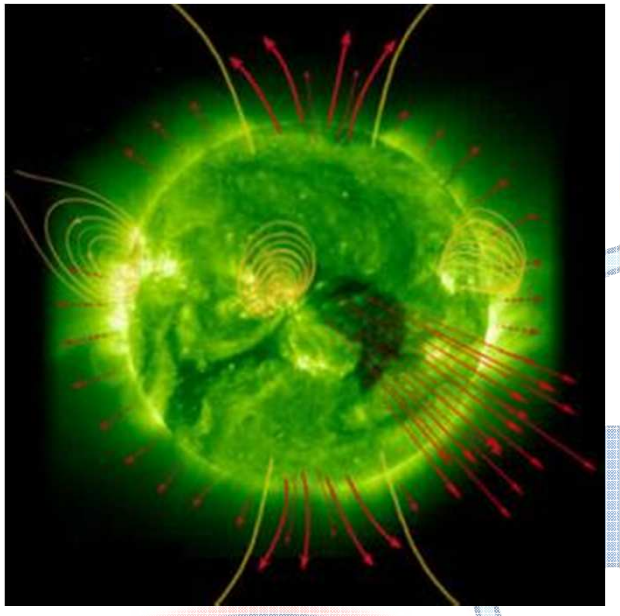
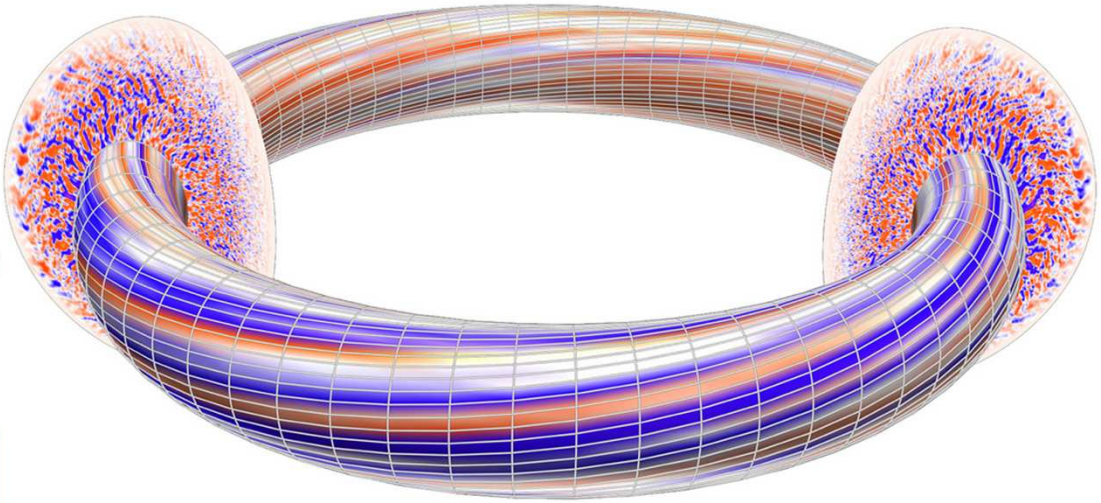
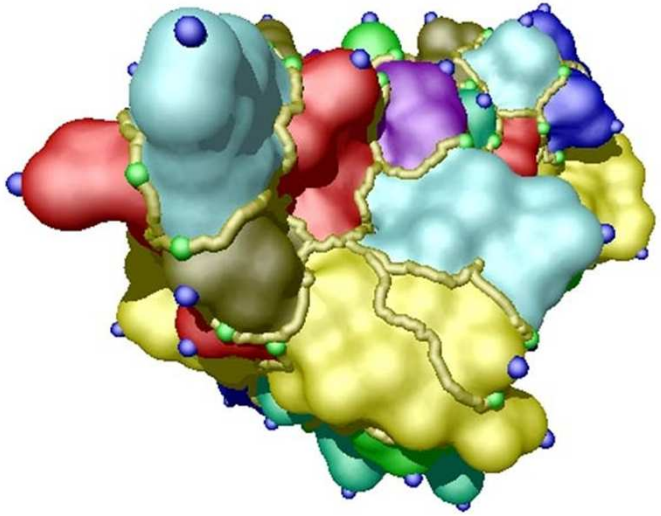
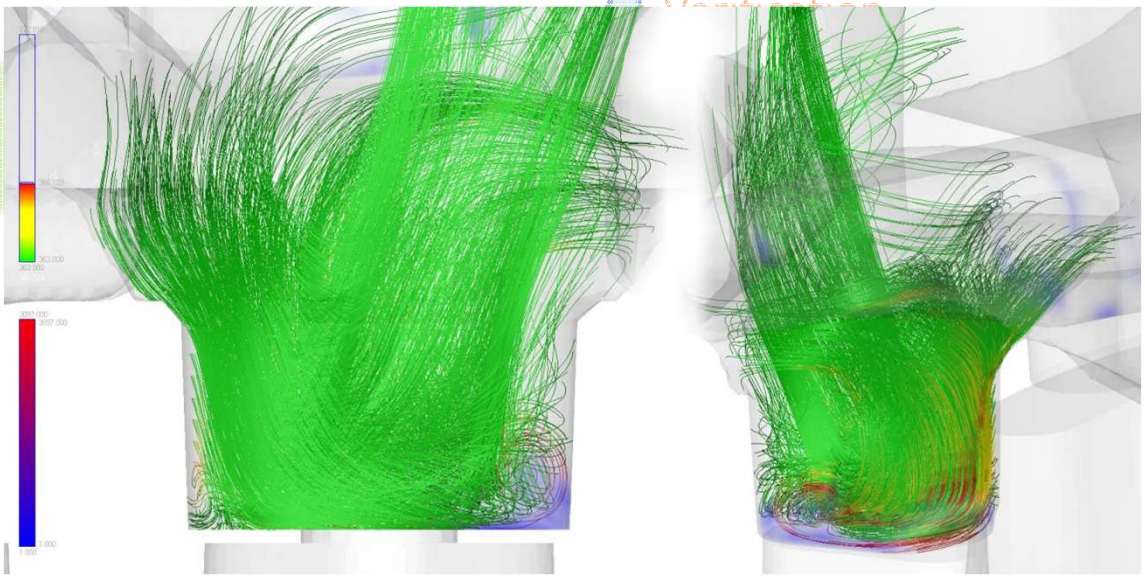








What is Data Analysis?

- From wiki:
  - **Analysis of data** is a process of inspecting, cleaning, transforming, and modeling **data** with the **goal** of highlighting useful information, suggesting conclusions, and supporting decision making. Data analysis has multiple facts and approaches, encompassing diverse techniques under a variety of names, in different business, science, and social science domains.

Different Data Analysis

- Depending on the type of data, there is **no a universal analysis framework** that works for all data!

- Structured vs. unstructured or semi-structured data analysis
  - *structured data*. Data that resides in fixed fields within a record or file. Relational databases and spreadsheets are examples of *structured data*. (clustering by attribute values)
  - *unstructured data*. Information that does not have a data model. Text data such as books, journals, documents, emails, social media data, and audio are examples of *unstructured data*.
  - Analysis techniques: **database techniques**, **data mining** and **text analytics**, respectively.

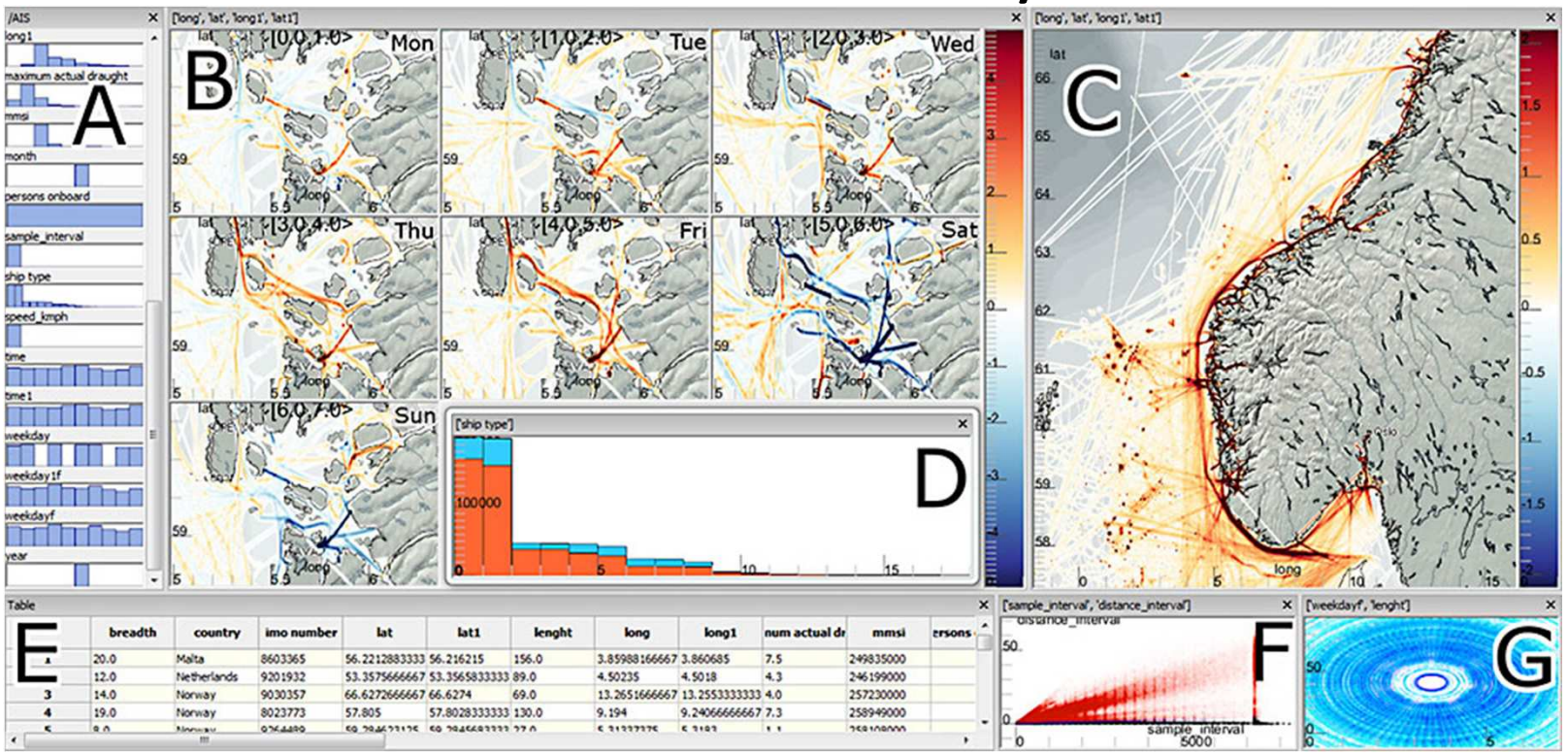
Image Analysis

- The data is already in the image form
- Digital image analysis
- Techniques: pattern recognition, digital geometry, and signal processing.

Data analysis has close link to data visualization

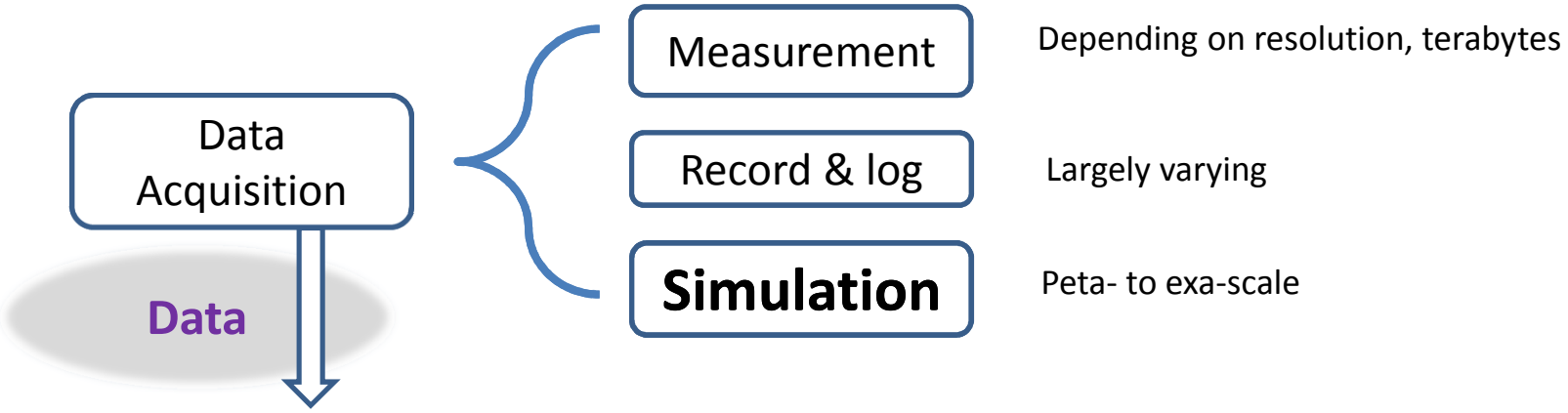
- Either the analysis results need to be visualized for efficient interpretation
  - A has relation with B, B has relation with C, C has relation with D, both D and C have relations with A
- Or the analysis is performed via visualization interface (visual exploration)

Data visual analytic



Source: http://www.ii.uib.no/vis/publications/publication/2010/lampe10differenceViews

Data Visual Analytic Pipeline



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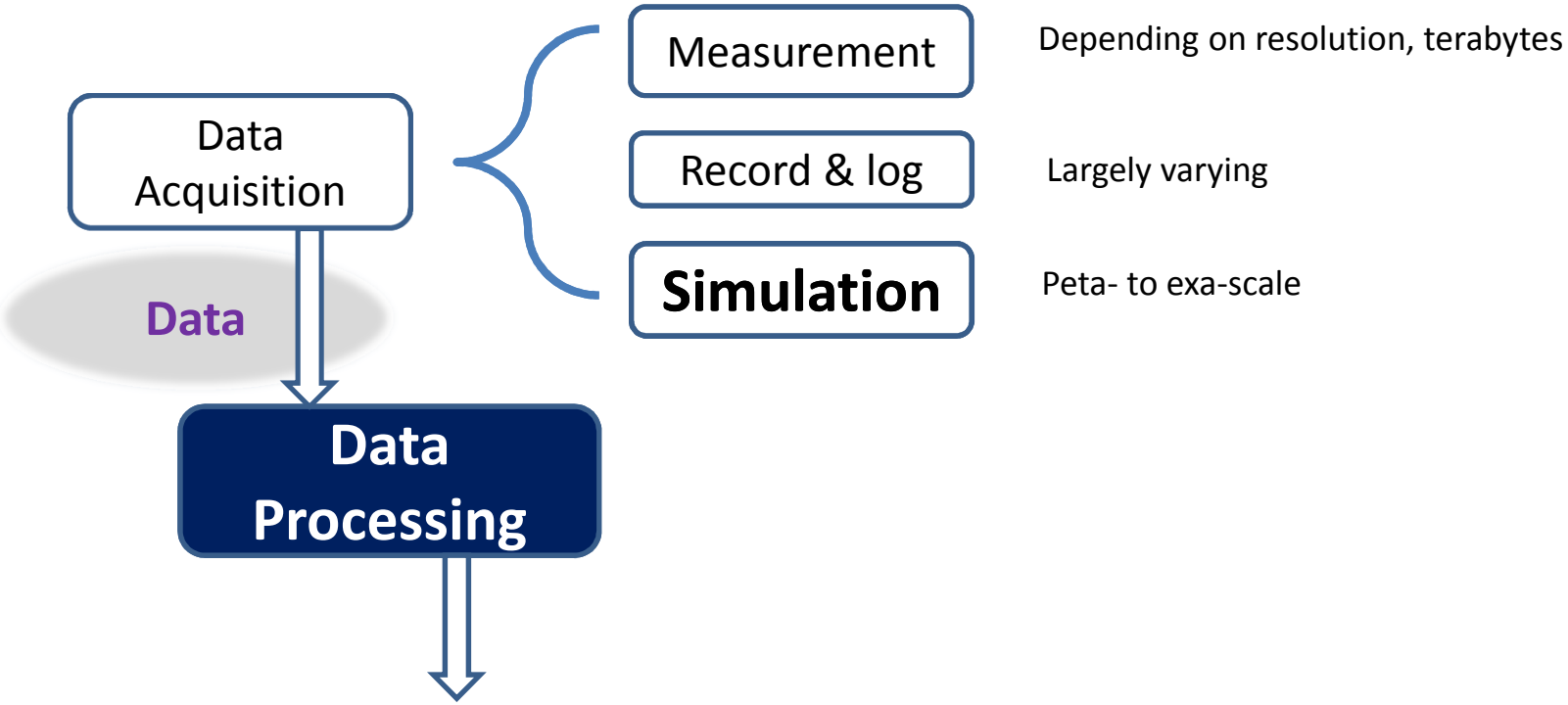

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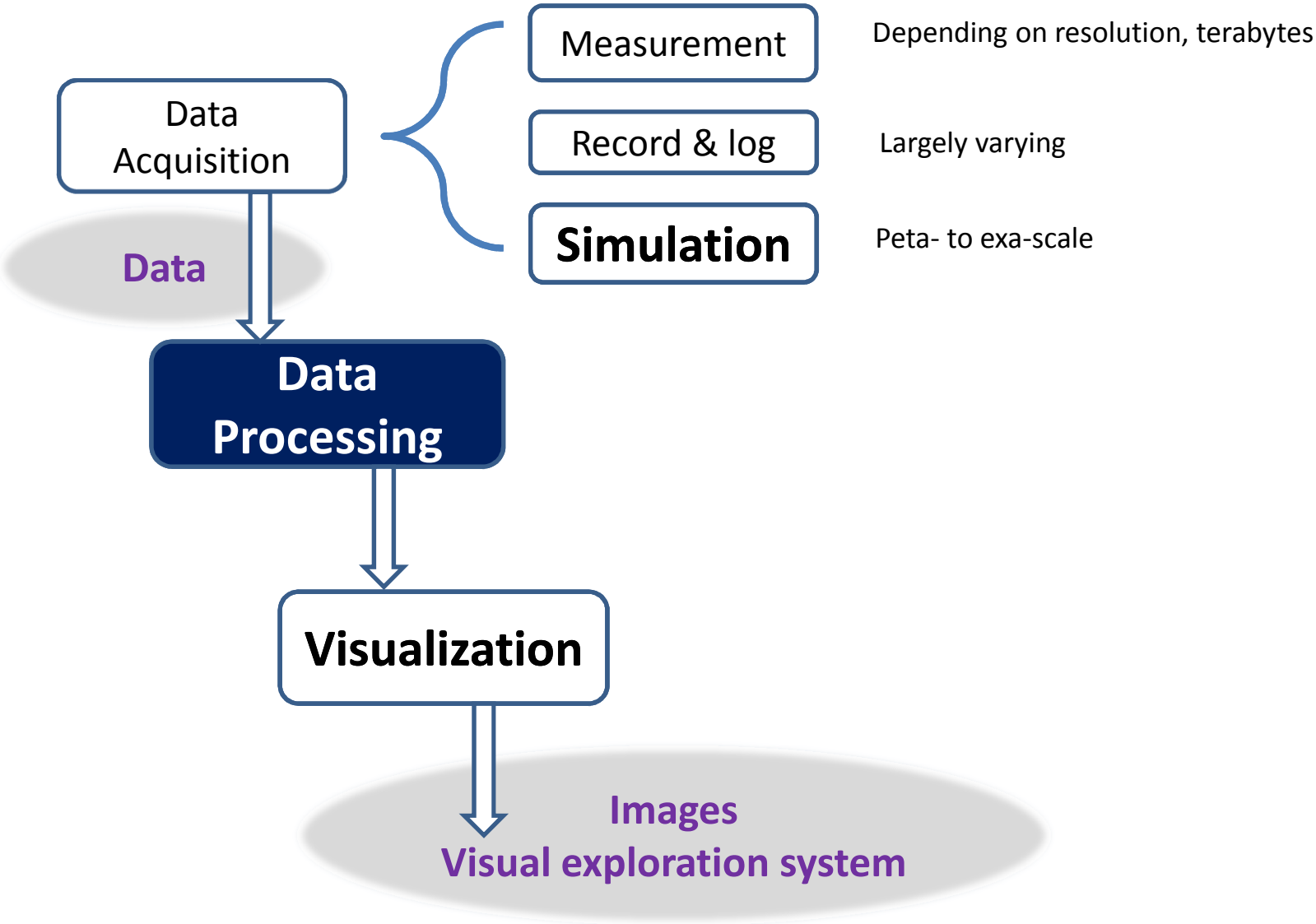

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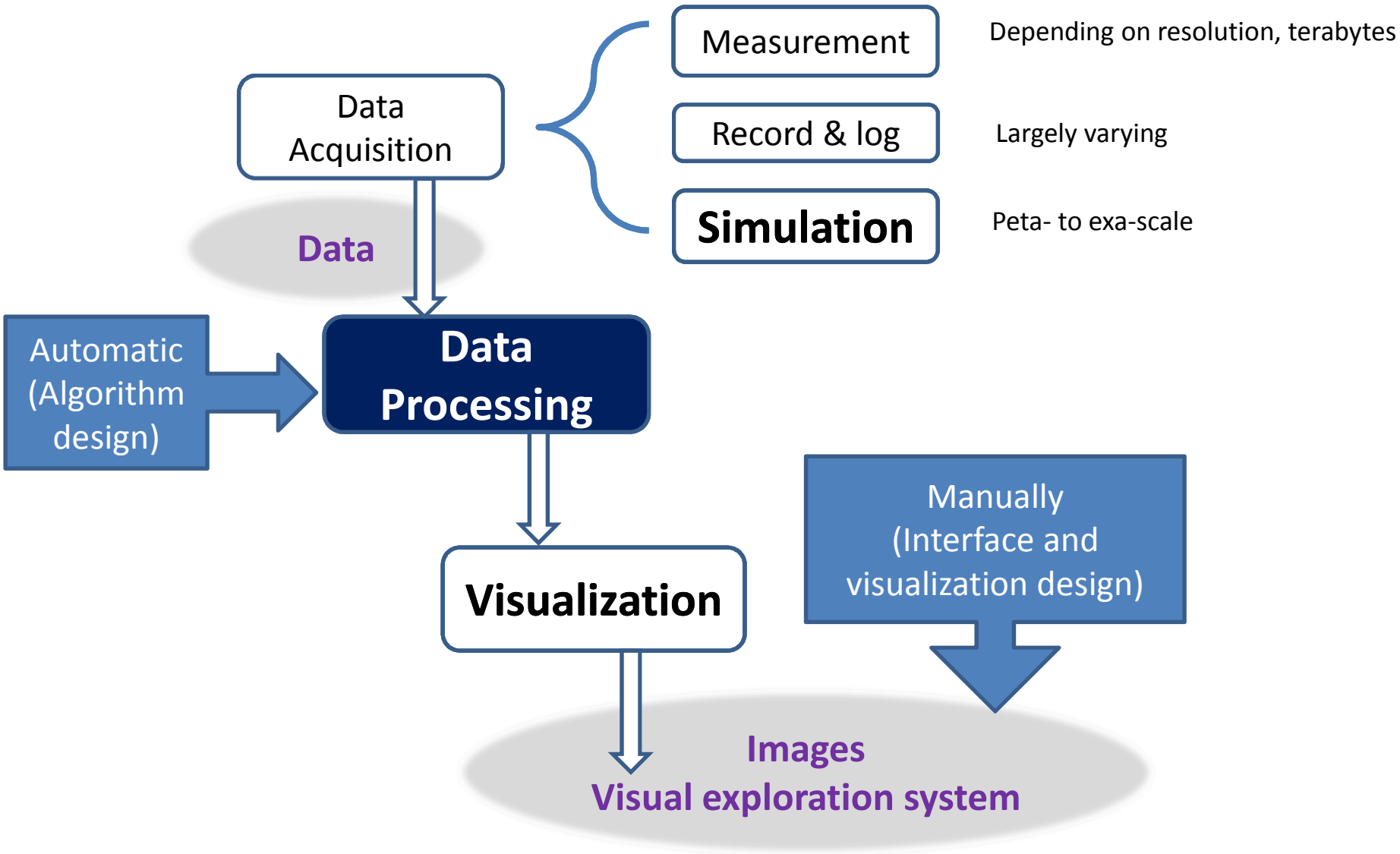
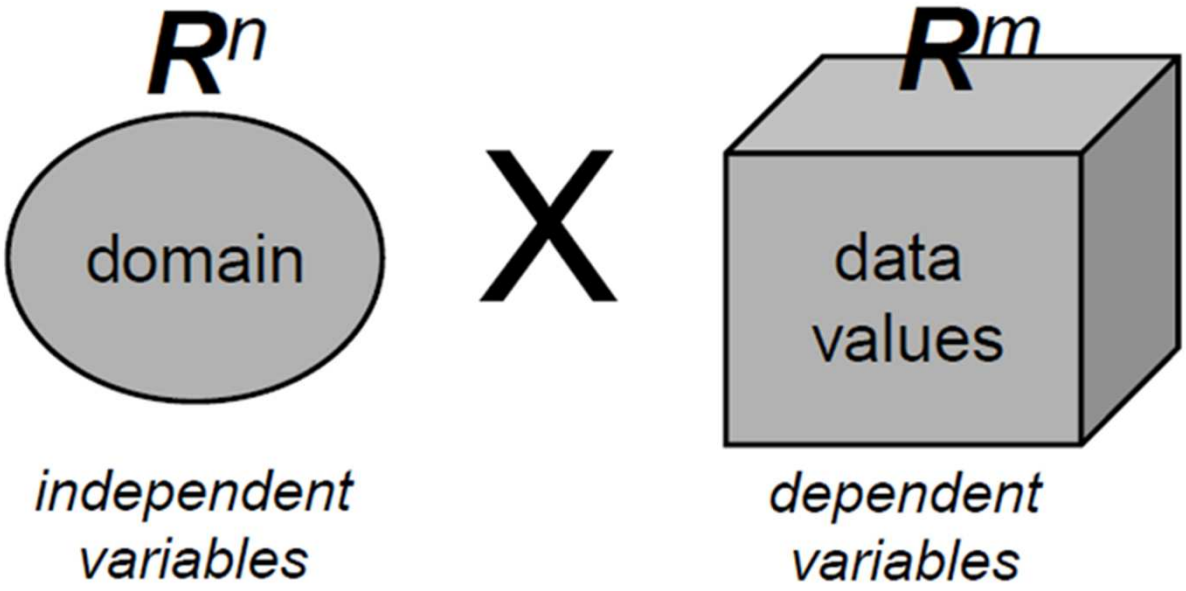


Data we are discussing in the class



Source: VIS, University of Stuttgart

Scientific data	3**D**+time (n<4)	Scalar/vector/tensor
Information data	n**D** (n>3)	Heterogeneous

SciVis vs. InfoVis

- Scientific visualization is mostly concerned with:
  - 2, 3, 4 dimensional, spatial or spatio-temporal data
  - discretized or sampled data (for continuous function)
- Information visualization focuses on:
  - high-dimensional, abstract data
  - discrete data
  - financial, statistical, etc.
  - visualization of large trees, networks, graphs
  - data mining: finding patterns, clusters, voids, outliers

By Ronald Peikert

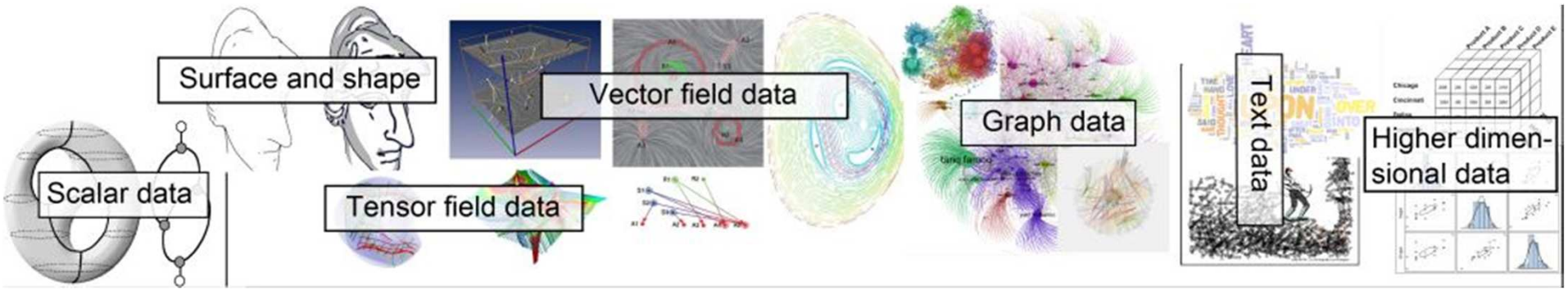
Goals and Topics

Goals of this Course

- Understand the different characteristics of different data types.
- Familiar with classical techniques for the analysis of various data types.
- Able to develop the customized analysis techniques and systems for the practical and your research needs.

Topics to Be Covered in this Course

- What will be covered?
  - Scalar data analysis for geometric data
  - Vector-valued data analysis for flow data
  - Tensor data analysis for medical and flow data
  - Graph data analysis
  - Text analytic
  - Higher dimensional data analysis



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  - Scalar data analysis for geometric data
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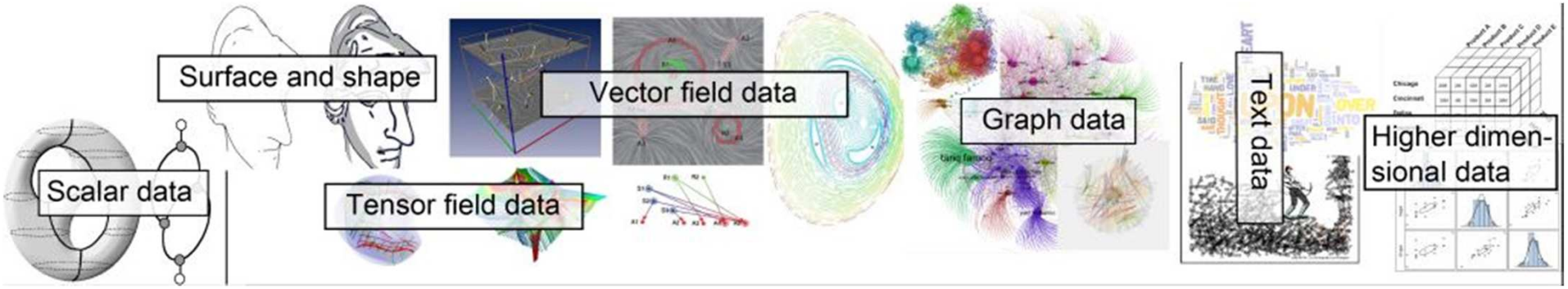
Scientific data

Information data

- What types of data do you have?

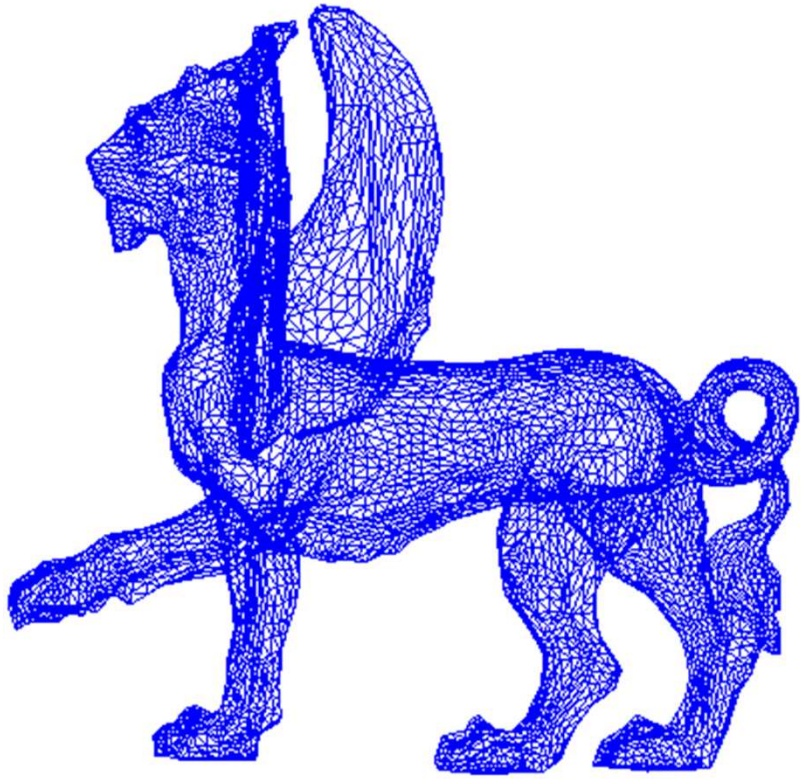


Surfaces

- Shape visualization
- Attributes:
  - Shading/lighting
  - Colors
  - Transparency
  - Silhouette
  - Feature curves
- Why do we care about it?

Surfaces

- Mesh



Data Structures

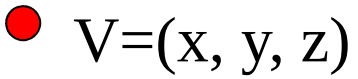
- Vertex
- Edge
- Face
- Corner
- Polyhedron

Polyhedron

- Vertex
  - vertex **vlist;
  - int num_verts, max_verts;
- Face **flist
  - face **flist;
  - int num_faces, max_faces;
- Corner **clist
  - corner **clist;
  - int num_corners, max_corners;
- Edge **elist
  - face **elist;
  - int num_edges, max_edges;

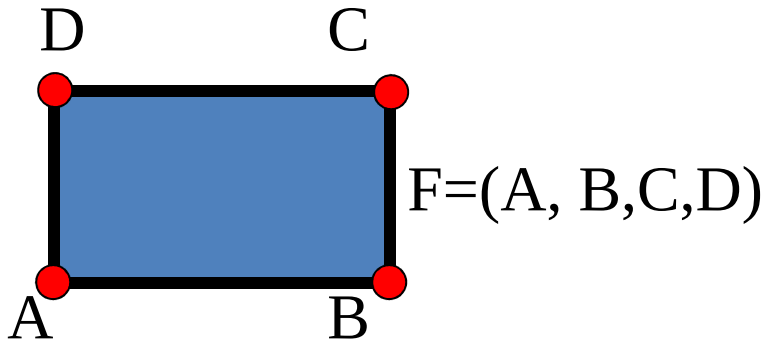
Vertex
(required)

- (x, y, z) - necessary
- (nx, ny, nz) – optional
- index – almost always needed
- List of faces incident to the vertex - almost always needed
- List of edges incident to the vertex – almost always needed
- Other types of data - optional



Face
(required)

- List of vertices - necessary
- index – almost always needed
- List of edges – almost always necessary
- Other types of data - optional



PLY format

- Header
  - Elements
  - Properties
- Data

PLY format of a Cube

```
ply
format ascii 1.0
comment created by platoply
element vertex 8
property float32 x
property float32 y
property float32 z
element face 6
property list uint8 int32 vertex_indices
end_header
-1 -1 -1
1 -1 -1
1 1 -1
-1 1 -1
-1 -1 1
1 -1 1
1 1 1
-1 1 1
4 0 1 2 3
4 5 4 7 6
4 6 2 1 5
4 3 7 4 0
4 7 3 2 6
4 5 1 0 4
```

header

Vertex list

Face list

Data

PLY format (header)

```
ply
format ascii 1.0
comment created by platoply
element vertex 8
property float32 x
property float32 y
property float32 z
element face 6
property list uint8 int32 vertex_indices
end_header
```

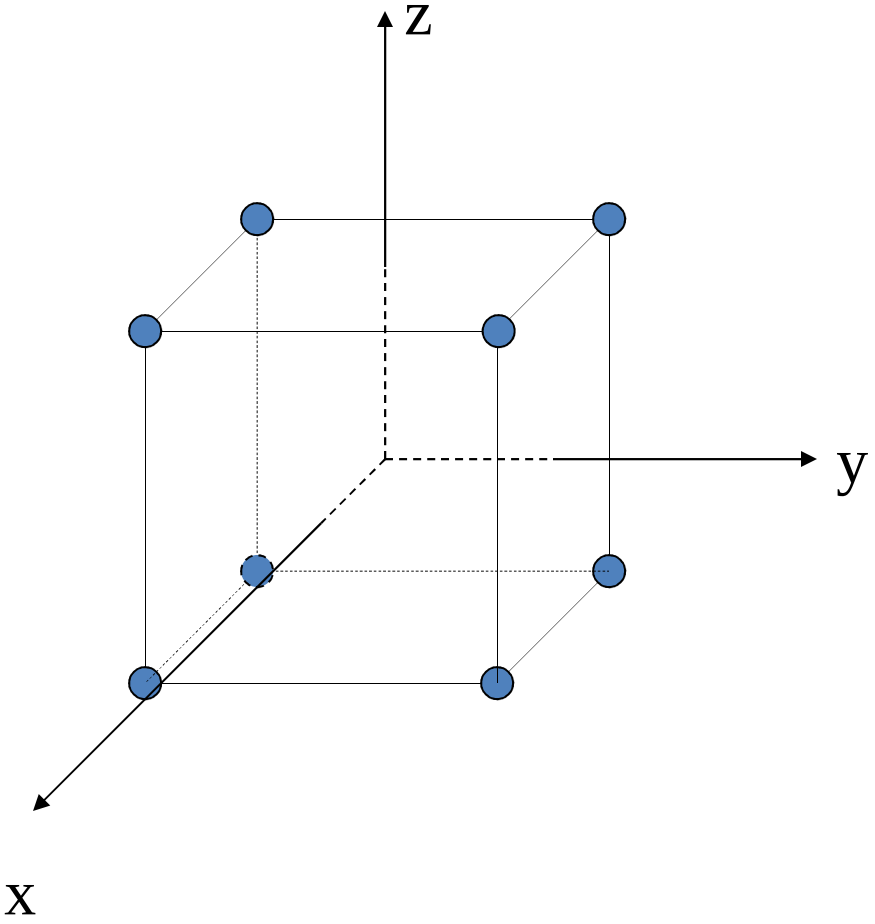
PLY format

-1 -1 -1
1 -1 -1
1 1 -1
-1 1 -1
-1 -1 1
1 -1 1
1 1 1
-1 1 1

Vertex list

4 0 1 2 3
4 5 4 7 6
4 6 2 1 5
4 3 7 4 0
4 7 3 2 6
4 5 1 0 4

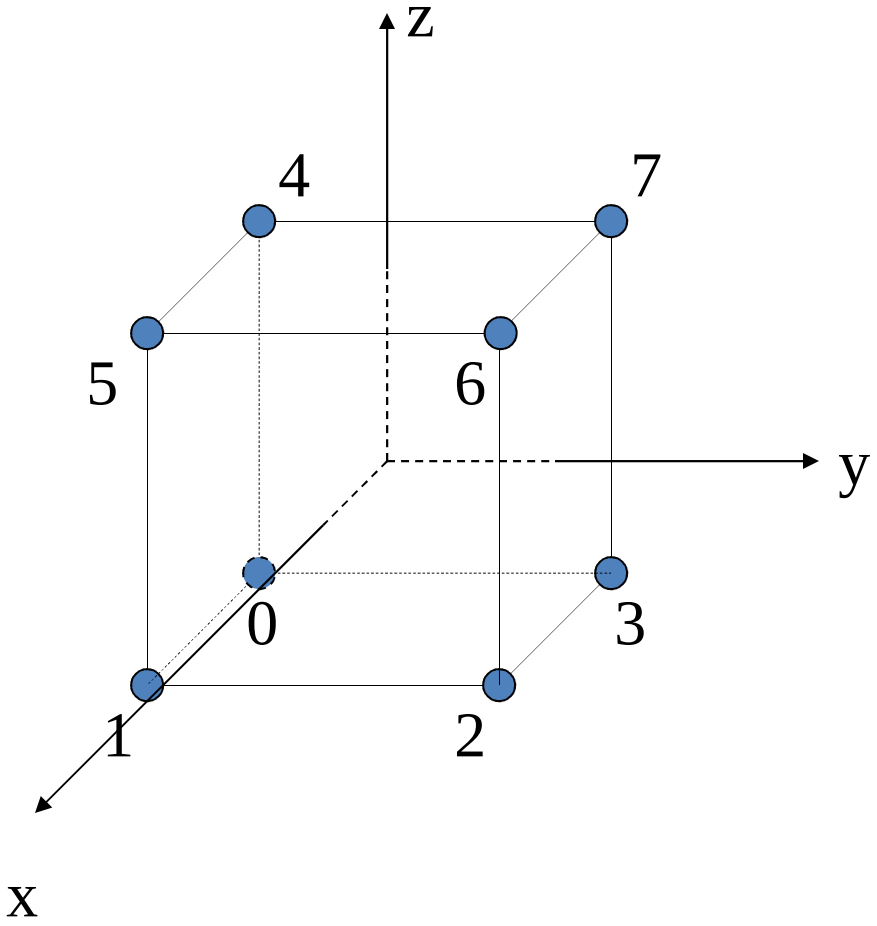
Face list



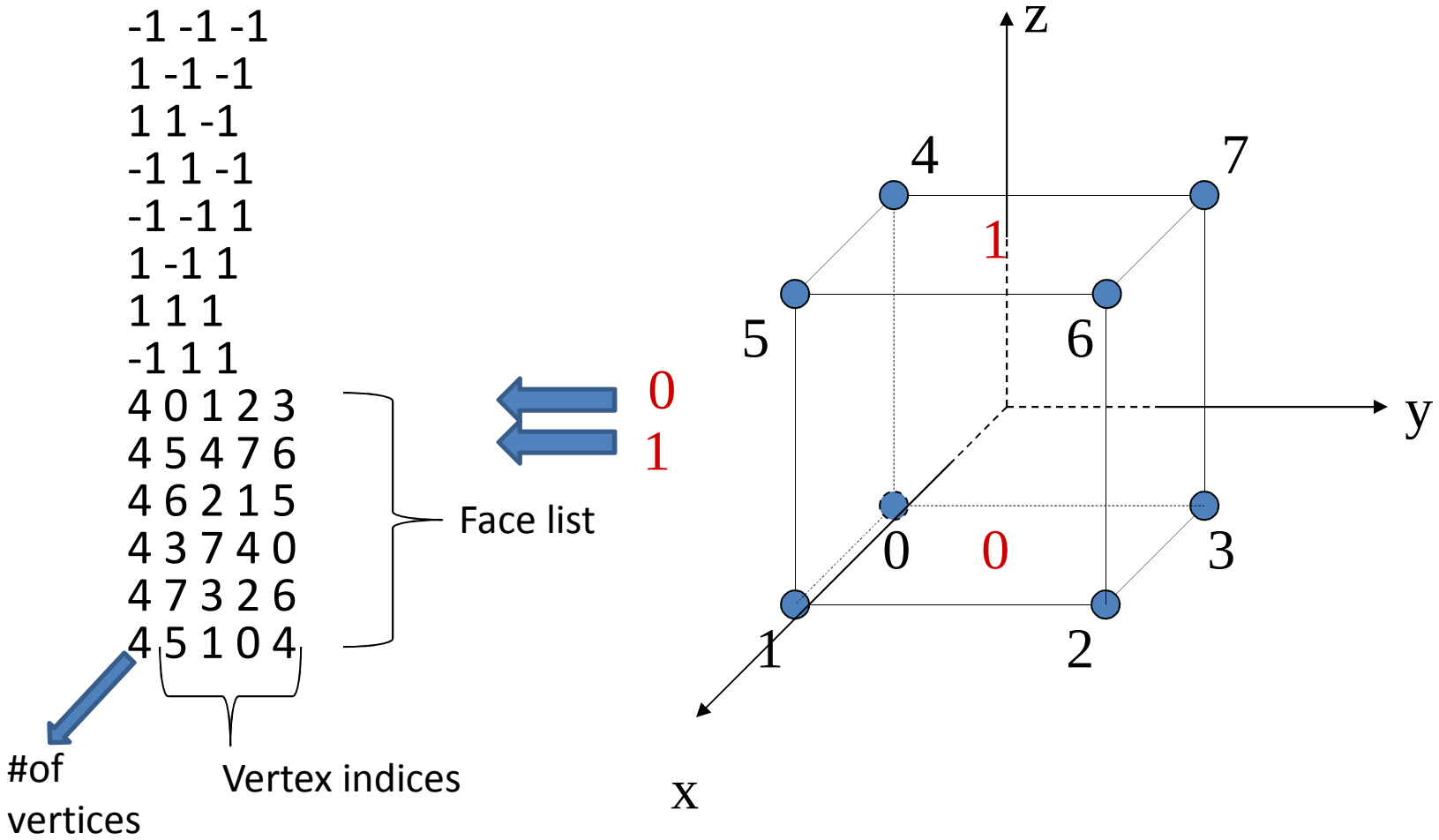
PLY format

X Y Z

-1 -1 -1
1 -1 -1
1 1 -1
-1 1 -1
-1 -1 1
1 -1 1
1 1 1
-1 1 1
4 0 1 2 3
4 5 4 7 6
4 6 2 1 5
4 3 7 4 0
4 7 3 2 6
4 5 1 0 4



PLY format


-1 -1 -1
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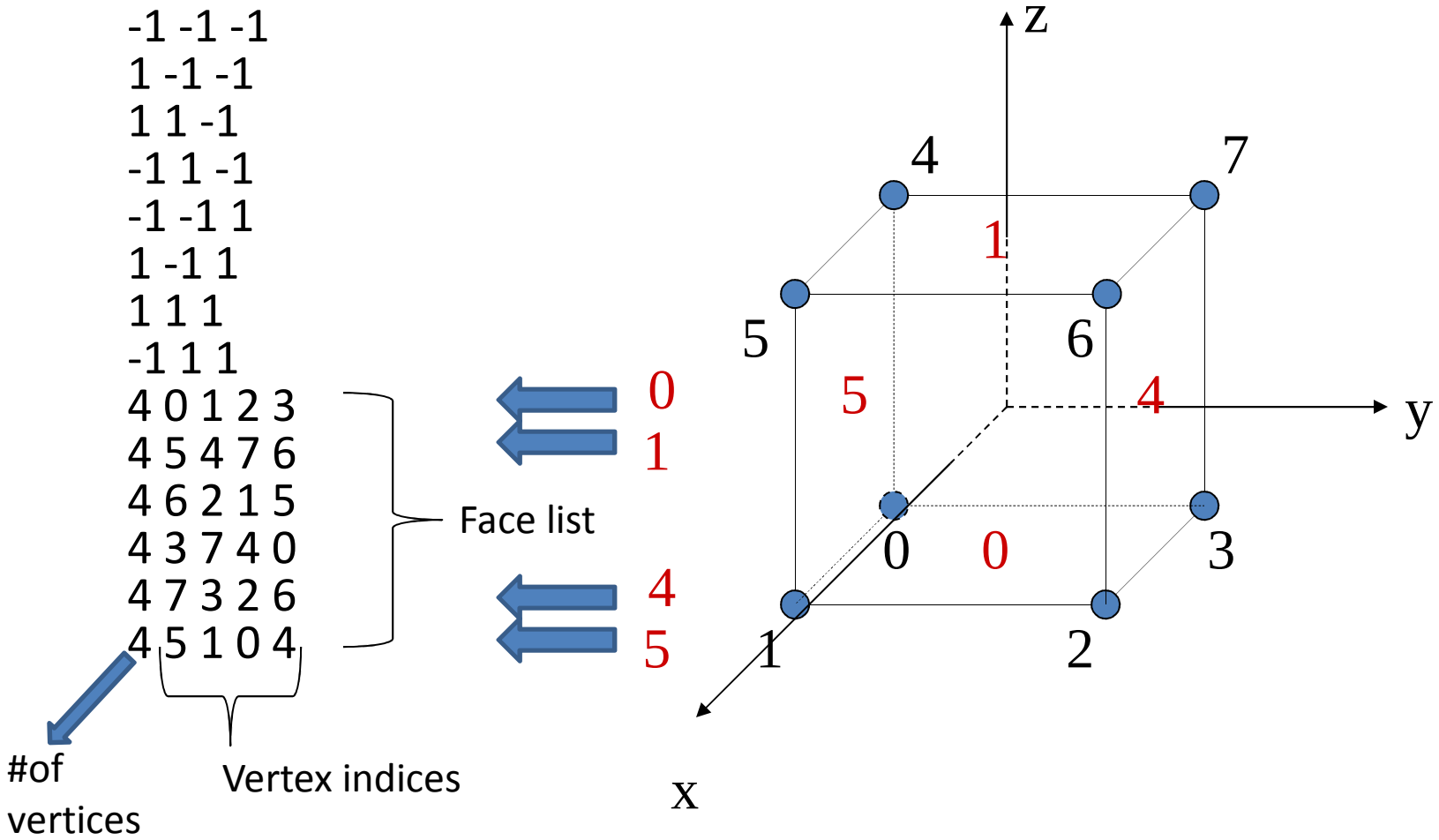
-1 1 -1
-1 -1 1
1 -1 1
1 1 1
-1 1 1
4 0 1 2 3
4 5 4 7 6
4 6 2 1 5
4 3 7 4 0
4 7 3 2 6
4 5 1 0 4
0
1
Face list
#of vertices
Vertex indices
z
y
x
4
7
5
6
0
3
1
2
1
0

PLY format


-1 -1 -1
1 -1 -1
1 1 -1
-1 1 -1
-1 -1 1
1 -1 1
1 1 1
-1 1 1
4 0 1 2 3
4 5 4 7 6
4 6 2 1 5
4 3 7 4 0
4 7 3 2 6
4 5 1 0 4
Face list
0
1
4
5
#of vertices
Vertex indices
z
y
x
4
7
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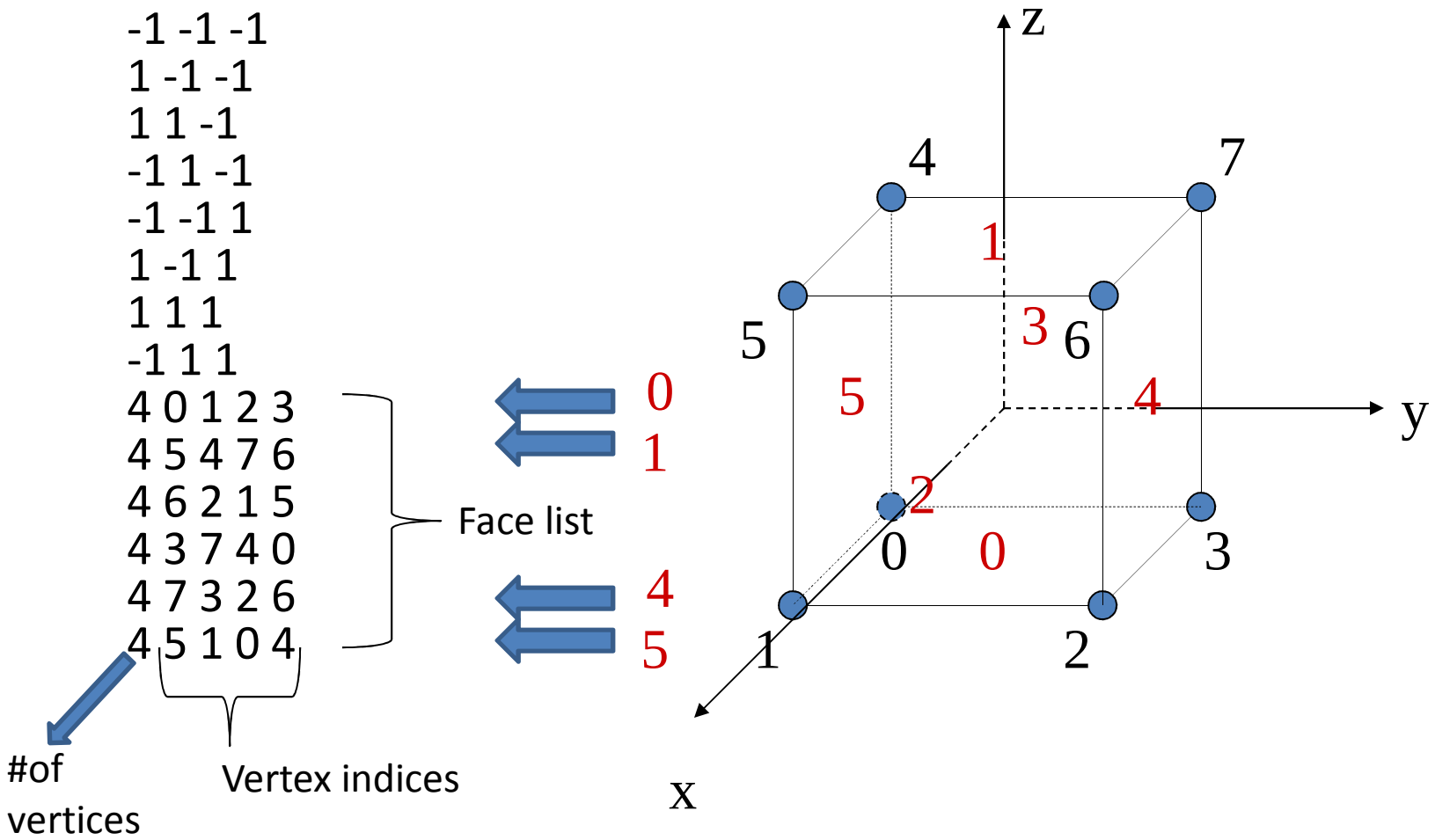
PLY format


-1 -1 -1
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-1 1 -1
-1 -1 1
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1 1 1
-1 1 1
4 0 1 2 3
4 5 4 7 6
4 6 2 1 5
4 3 7 4 0
4 7 3 2 6
4 5 1 0 4
Face list
0
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#of vertices
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z
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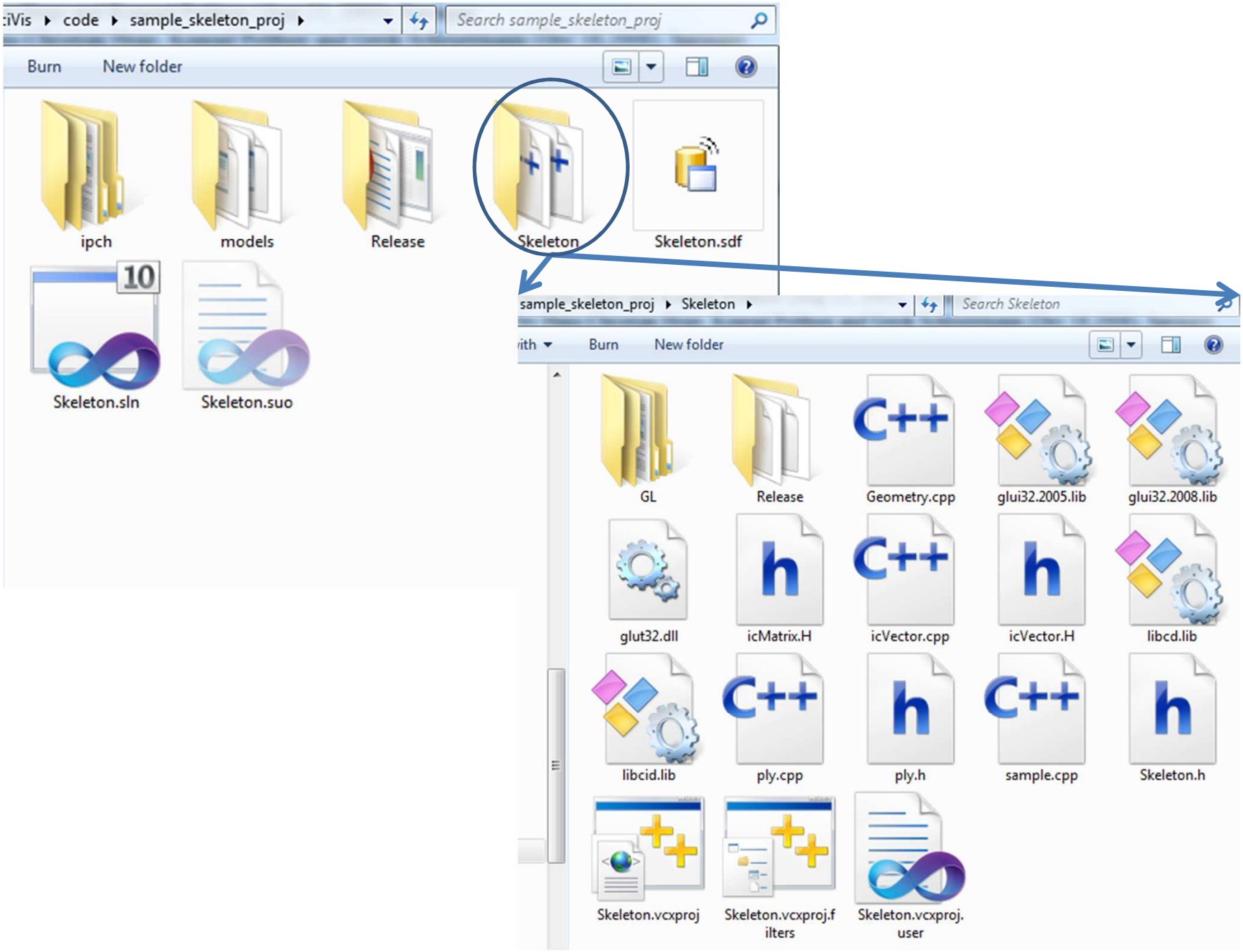
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glui32.2008.lib
glut32.dll
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icVector.cpp
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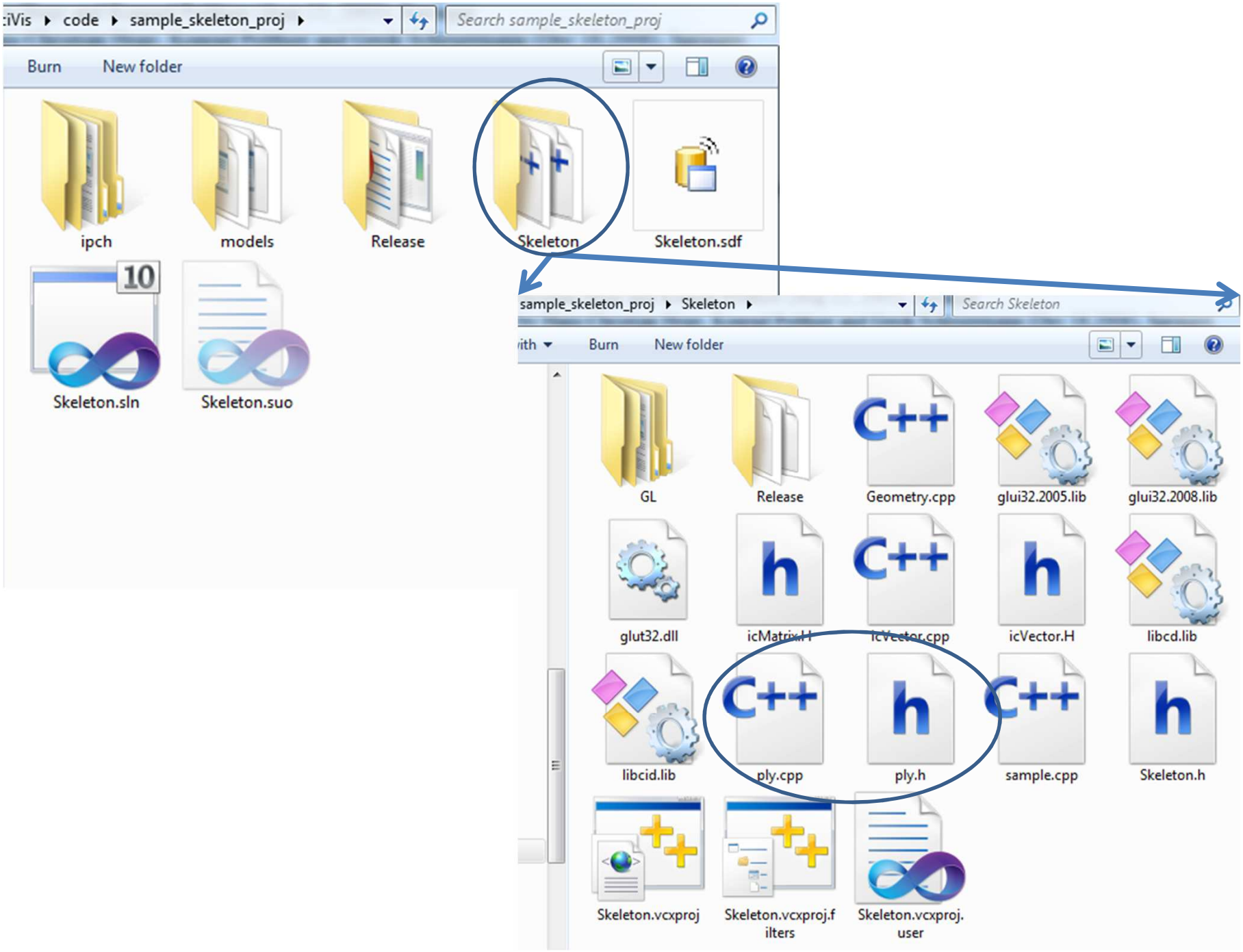
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Search Skeleton
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Release
Geometry.cpp
glui32.2005.lib
glui32.2008.lib
glut32.dll
icVector.H
libcd.lib
libcid.lib
ply.cpp
ply.h
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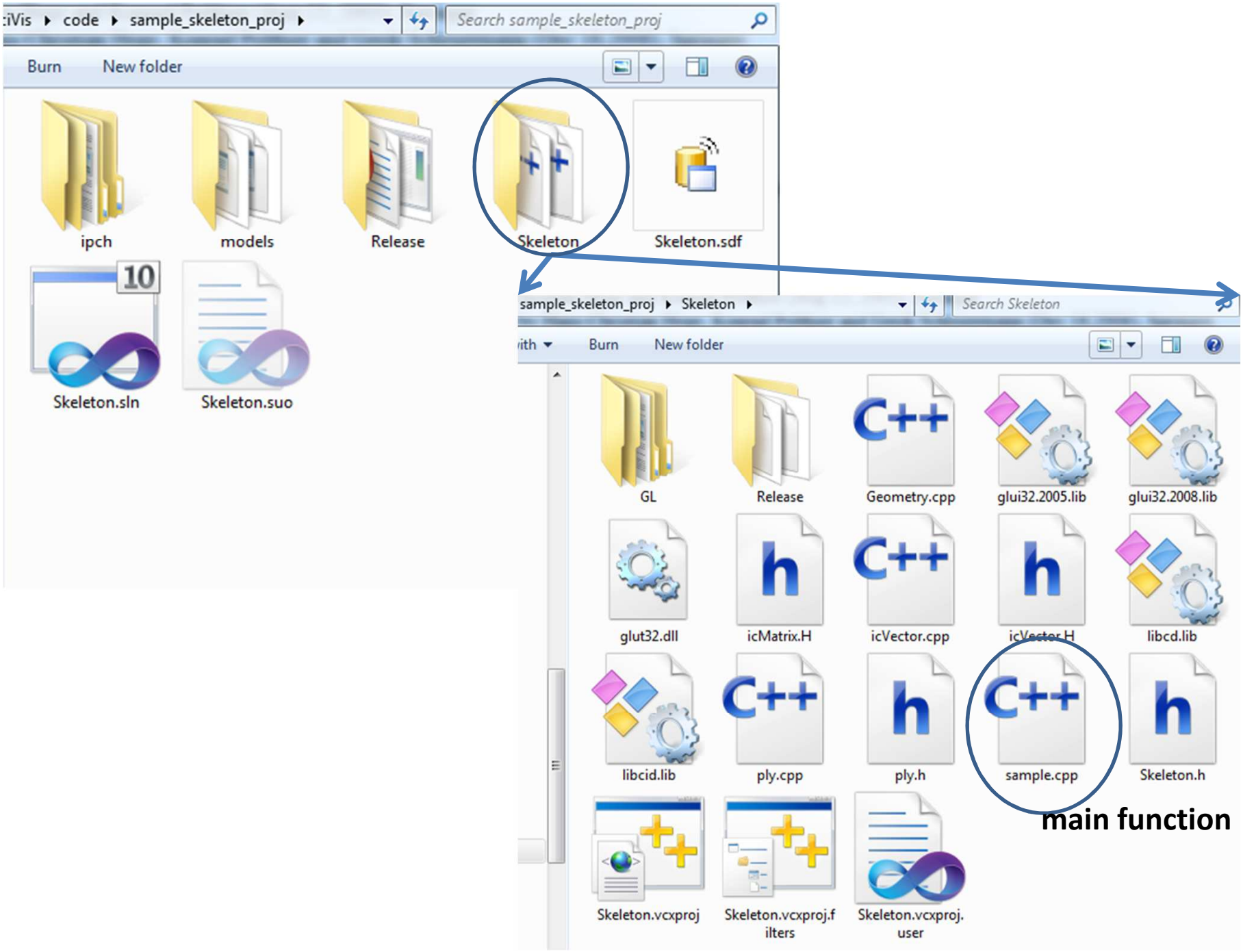
Skeleton.h
Skeleton.vcxproj
Skeleton.vcxproj.filters
Skeleton.vcxproj.user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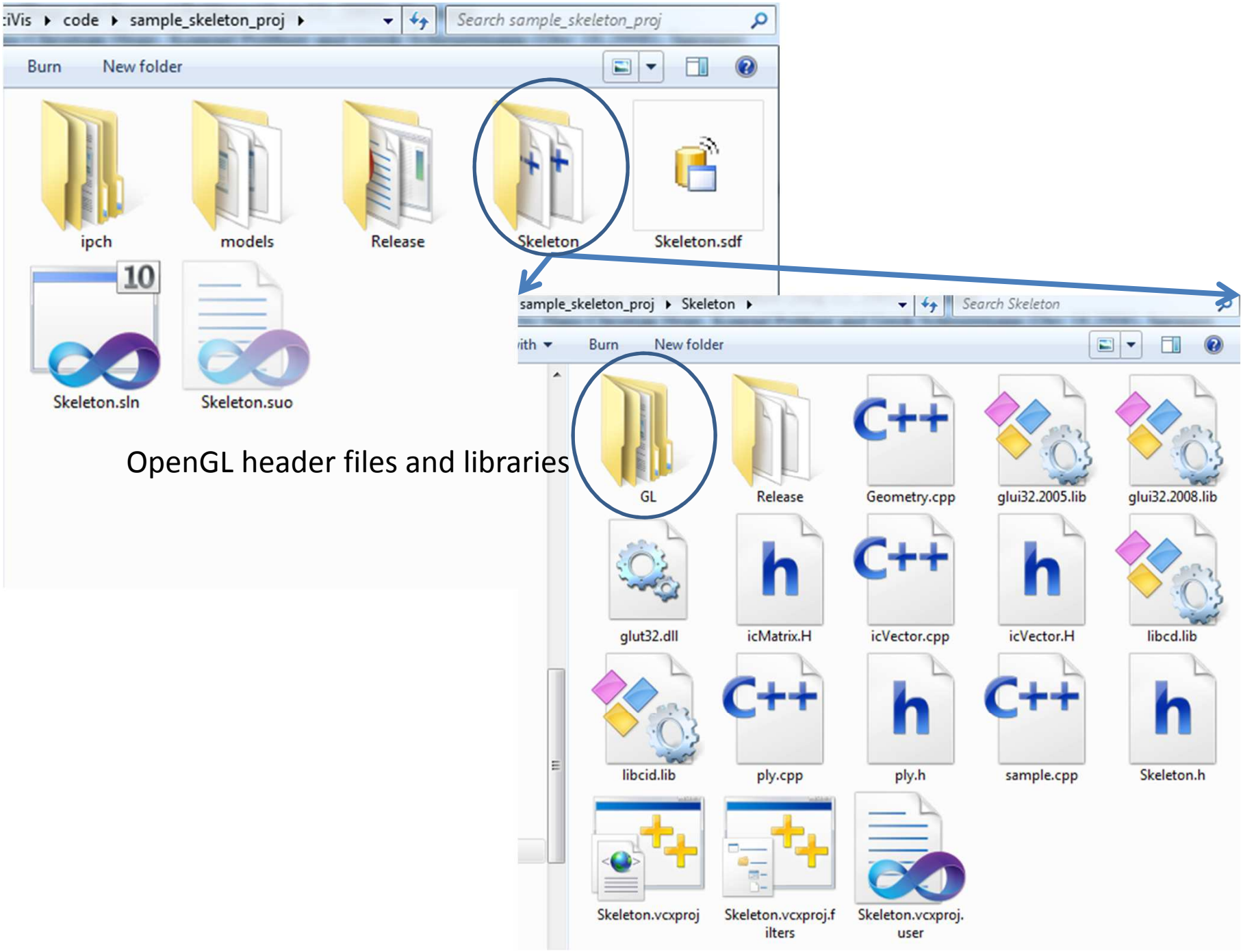
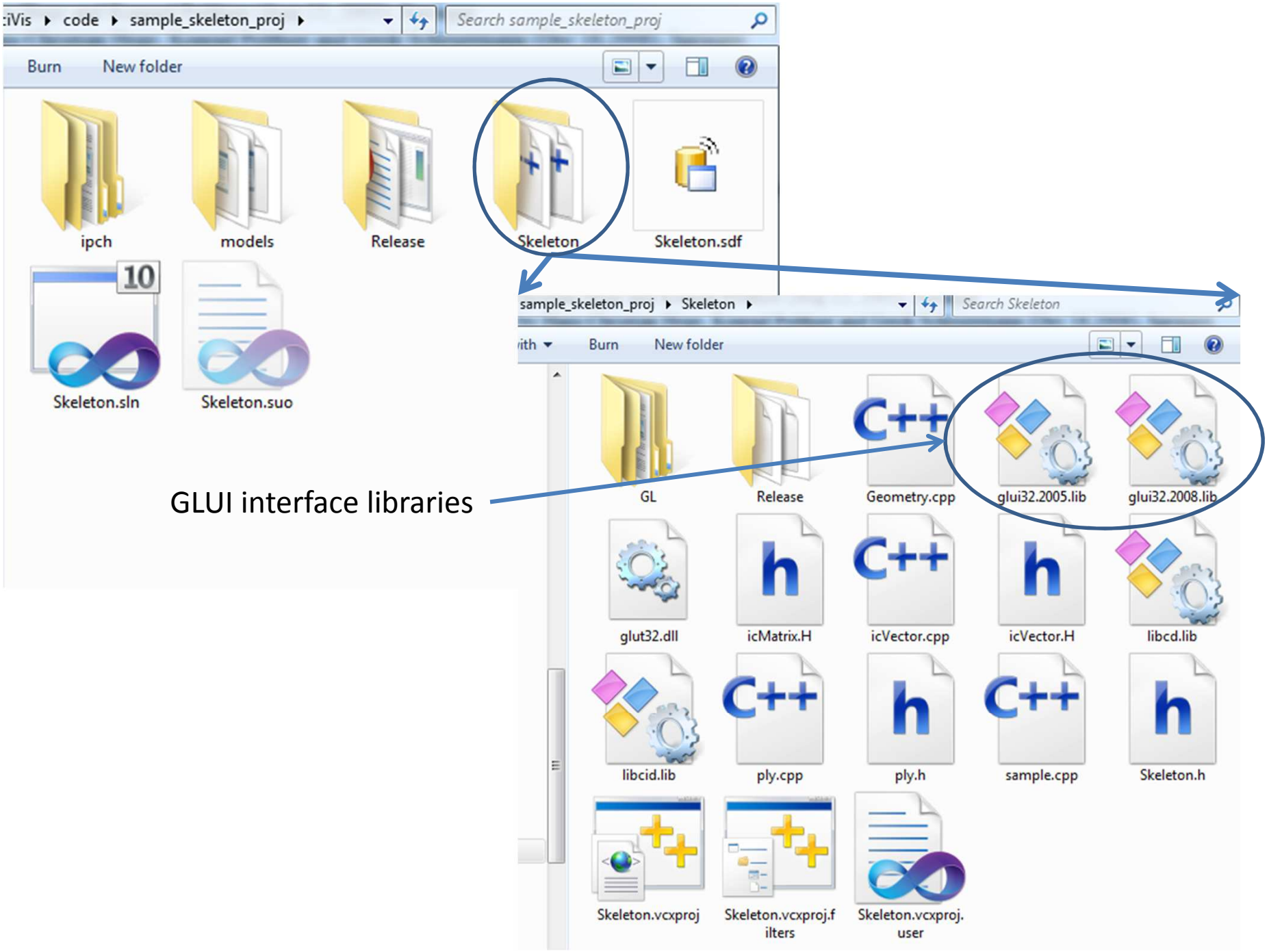
GL
Release
Geometry.cpp
glui32.2005.lib
glui32.2008.lib
glut32.dll
icMatrix.H
icVector.cpp
icVector.H
libcd.lib
libcid.lib
ply.cpp
ply.h
sample.cpp
Skeleton.h
Skeleton.vcxproj
Skeleton.vcxproj.filters
Skeleton.vcxproj.user
main function



OpenGL header files and libraries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models
Release
Skeleton
Skeleton.sdf
Skeleton.sln
Skeleton.suo
GLUI interface libraries
sample_skeleton_proj ▸ Skeleton ▸
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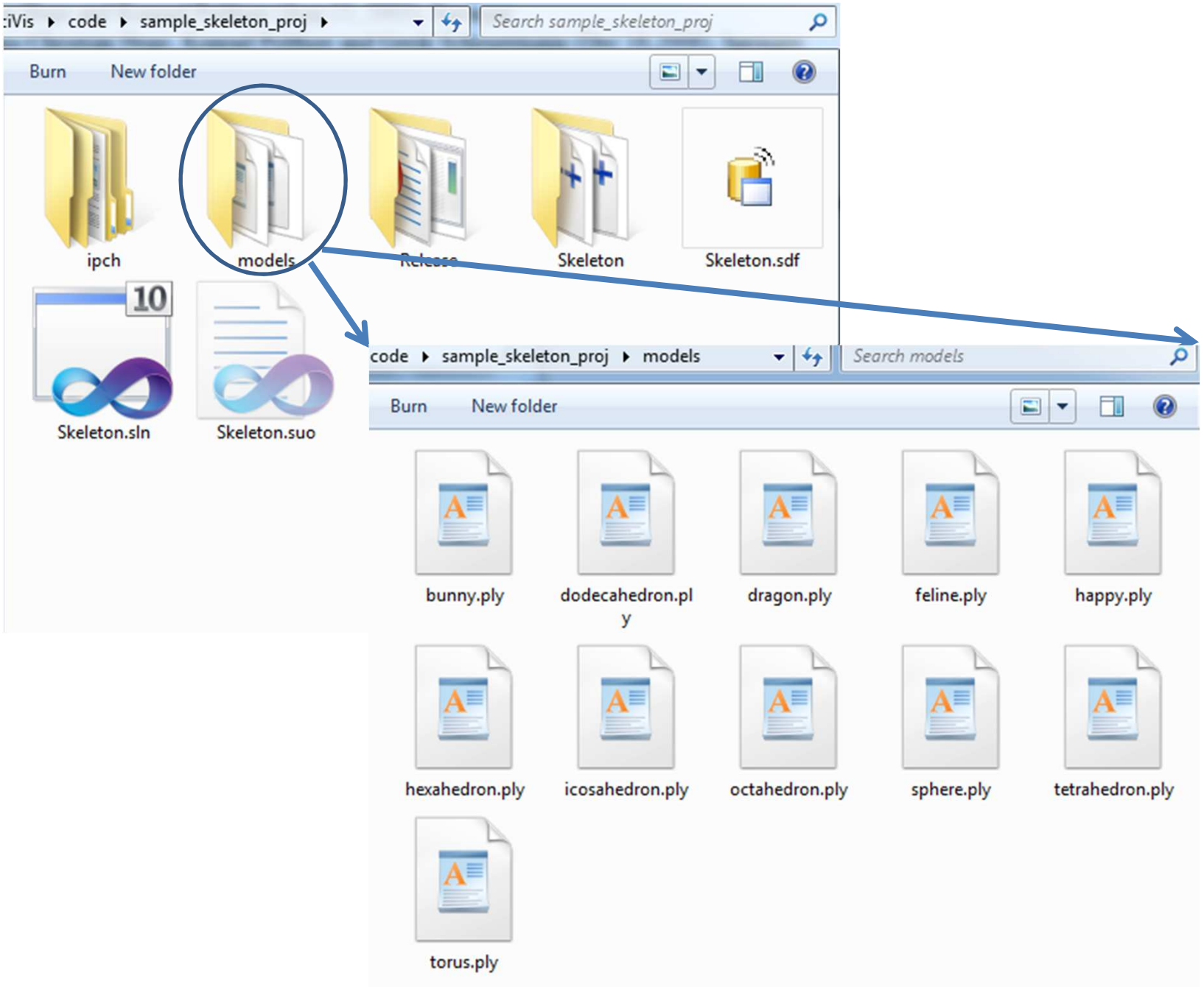
Geometry.cpp
glui32.2005.lib
glui32.2008.lib
glut32.dll
icMatrix.H
icVector.cpp
icVector.H
libcd.lib
libcid.lib
ply.cpp
ply.h
sample.cpp
Skeleton.h
Skeleton.vcxproj
Skeleton.vcxproj.filters
Skeleton.vcxproj.user


iVis ▸ code ▸ sample_skeleton_proj ▸
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New folder
bunny.ply
dodecahedron.ply
dragon.ply
feline.ply
happy.ply
hexahedron.ply
icosahedron.ply
octahedron.ply
sphere.ply
tetrahedron.ply
torus.ply

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