

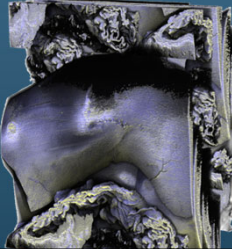
Master informatique
CHPS

UNIVERSITÉ DE REIMS
CHAMPAGNE-ARDENNE

Interactive High-Performance Visualization

Master CHPS CHPS0941
Laurent Lucas

Overview – 06/10/2022



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Outline

- Syllabus and Prerequisites for this course
- Overview of Visualization: Scientific Visualization vs. Information Visualization
- Projects Overview

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Syllabus

- https://romeo.univ-reims.fr/chps/3_master-2.html

Visualisation haute performance interactive

Semestre : 3
Responsable : LAURENT LUCAS
ECTS : 4
CHPS0941

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Département : Informatique, IUT Reims
Bureau : C207
Volume horaire : 144 heures
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Volume horaire		TP		COURS		Total	
Nombre	Durée	Nombre	Durée	Nombre	Durée	Nombre	Durée
1	2h	1	2h	1	2h	2	4h

Modalités de contrôle des connaissances

Epreuves		Notes		Projet		Total	
Points	Coef	Points	Coef	Points	Coef	Points	Coef
100%	1	100%	1	100%	1	100%	1

Objectifs : Ce cours présente les principes techniques de représentation, modélisation, et visualisation de grands ensembles de données tridimensionnelles structurées ou réparties, et permet de visualiser des données expérimentales ou de simulation. Les images sont visualisées dans des environnements interactifs et permettent de mieux comprendre certains phénomènes, dans des domaines aussi variés que la médecine, la chimie, les sciences de la terre ou l'industrie manufacturière.

Compétences spécifiques visées : comprendre le fonctionnement général des principales classes d'algorithmes de visualisation.

Compétences générales visées : être capable de proposer un algorithme de visualisation sur la base d'un problème donné.

Connaissances requises : C++, UNIX, OpenGL, CUDA.

Programme :

- 1 - Introduction
 - Historique, ergonomie cognitive et boucle d'interaction modélisation/observation
 - Propriétés de la vision, l'occlusion et l'élaboration des données
- 2 - Visualisation scientifique vs. d'information et analyse visuelle
 - Champ de vecteurs (streaming, LSC, ...) vs. Tenseurs
 - Appareils haptiques
- 3 - Visualisation et imagerie bio-médicale
 - Tomographie et reconstruction de surfaces (marching cubes, ...)
- 4 - Visualisation d'images, séquences, DVR, ...
- 5 - Visualisation multi-caméras
- 6 - Visualisation de données éparpillées, hiérarchiques ou en réseau
 - Approches sort final vs. sort lat
- 7 - Visualisation immersive (via Unity3D)
- 8 - Logiciels et principaux frameworks pour la visualisation
 - VTK, ParaView, CUDA, Cytoscape, Python (NumPy, PyViz, Mayavi, ...) et JS (WebGL, ...)



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Prerequisites for this course

- C++, OpenGL and CUDA programming skills are recommended
- But you can also be proficient with Python to take this course
- Or any other programming framework or tool that allows you to interactively display an image

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Expectations and grading

- This is a projects-driven class.
- The projects will help you learn the theory and techniques behind scientific visualization, but they will also help you become better programmers.
- The projects in this class will be hard work for those who have not done significant programming before. It is difficult to quote exactly how much time, since there is variation in background and programming skill.
- I expect those who have less developed programming skills will find this class to be a considerable effort, but also that they will have significant improvement by the end of the course.
- Grading will be based on a project for the first 50% and a bibliographic study for the remaining 50%.

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This class in a Nutshell...

- Most of the learning will happen with projects. The lectures are designed to help you do the projects.
- Part 1: Learn the basics behind scientific visualization.
- Part 2: Focus on advanced concepts.

So ...

- Please ask questions.
- Please ask me to slow down.
- Please give feedback.

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Course materials

- Code samples will be provided in addition of dedicated APIs
- References - books and papers - will be also proposed



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Scientific visualization vs. Information visualization

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Some quotations

- « L'œil ... fenêtre de l'âme est la principale voie par laquelle notre intellect peut apprécier pleinement l'œuvre infinie de la nature »

Léonard de Vinci
1452-1519

- « L'image calculée et interactive est un champ de découverte qu'aucun autre moyen de communication ne peut égaler. Celui qui nierait l'intérêt de cet outil devrait tout autant refuser à l'astronome l'usage de ses yeux pour contempler les cieux »

Expériences virtuelles et virtualités expérimentales
CNET, 1993

- « The purpose of computing is insight, not numbers »

Numerical Methods for Scientists and Engineers
Richard Hamming, Mc Graw-Hill, 1962

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Some quotations

- « Visualization is a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualization offers a method for seeing the unseen. It enriches the process of scientific discovery and fosters profound and unexpected insights. In many fields it is already revolutionizing the way scientists do science »

McCormick, B.H., T.A. DeFanti, M.D. Brown
Visualization in Scientific Computing, Computer Graphics 21(6), November 1987

- « Scientific data visualization supports scientists and relations, to prove or disprove hypotheses, and discover new phenomena using graphical techniques. The primary objective in data visualization is to gain insight into an information space by mapping data onto graphical primitives »

H. Senay, E. Ignatius
A Knowledge-Based System for Visualization Design, IEEE Computer Graphics and Applications, pp. 36-47, November 1994

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Agenda

- Preamble
- Introduction and a bit of history
- Definition and aims
- Classification of visualization approaches
 - Scientific Visualisation (SciVis)
 - Information Visualisation (InfoVis)
- Models taxonomy
 - Continuous vs. Discrete
 - Model vs. Data
 - Spatialisation

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Preamble

- The need to explore the core of data
 - Many people or institutions have and produce data that can « hide » fundamental relationships such as...
 - ... banks, researchers (biologists, meteorologists, physicists, geographers, etc.), engineers, doctors, urban planners, etc.
 - They would like to be able to graphically visualize these data, possibly interact with them and be able to exclaim...
- We are not discussing here the statistical analysis that might - or might not - follow.
- We are fundamentally interested in visual acquisition of knowledge embedded or hidden in the data

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Introduction

- Visualization is quite old  (L. Da Vinci and Water)
 - But as a scientific discipline since 1987 (1st dedicated conference in 1990)
- What is visualization
 - Wikipedia states « Visualization is any technique for creating images, diagrams, or animations to communicate a message »
 - Often an intuitive step
 - Data with ever increasing sizes → graphical approach necessary
- Data visualization
- Scientifics (abstract data, ...)
 - Physics (fluids, ...)
 - Medical (X-ray scanner, RMN, ...)
 - Technical (mechanical components, ...)

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Introduction

- Visualizing - Seeing the Unseeable
 - Build a mental model or vision of...
 - Human (cognitive) activity not performed by a computer
 - Cognitive transfer → perceptual
 - However, computers can help through visualization software tools
 - Visualization takes advantage of our powerful visual faculties

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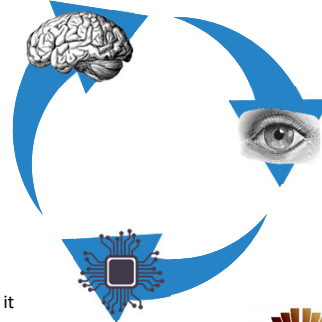
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Introduction

- Visualization aims to combine the powerful visual faculties of humans with the computational capabilities of machines.
- Pipeline: model/observation interaction loop
 - 1 Overview of the situation
 - Get an overview of the data collection
 - 2 Zoom in
 - Navigate to points of interest
 - 3 Filter
 - Hide uninteresting elements
 - 4 Details on demand
 - Select an item or a group of items to learn more about it



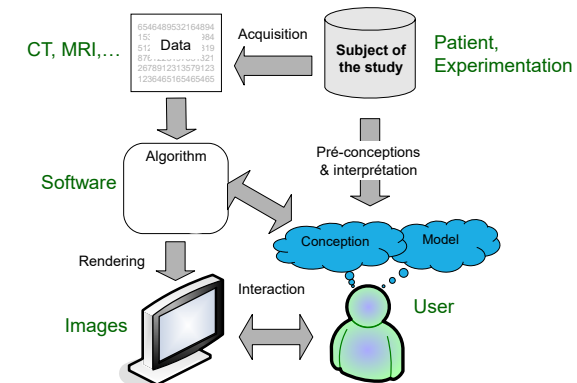
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Introduction



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Introduction

- Visualization, ...
 - .. to explore
 - nothing is known, visualization used for data exploration
 - ... to analyze
 - there are hypotheses, visualization used for verification or falsification
 - ... to present
 - "everything" known about the data, visualization used for communication of results

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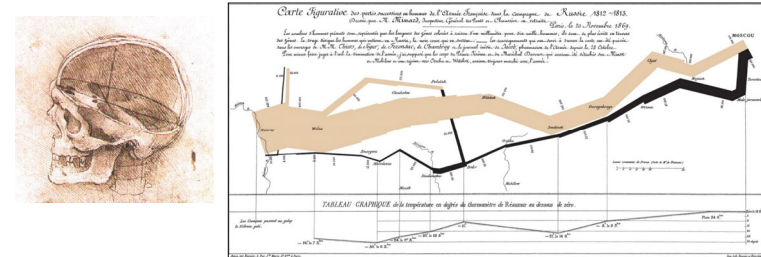
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Brief history

- First step towards cognitive ergonomics
 - Léonard de Vinci (Traité d'anatomie, 1489)
 - 1812, Napoleon's marching - Charles-Joseph Minard's map (1781-1870) visualized the army size and the temperature during the Russian retreat



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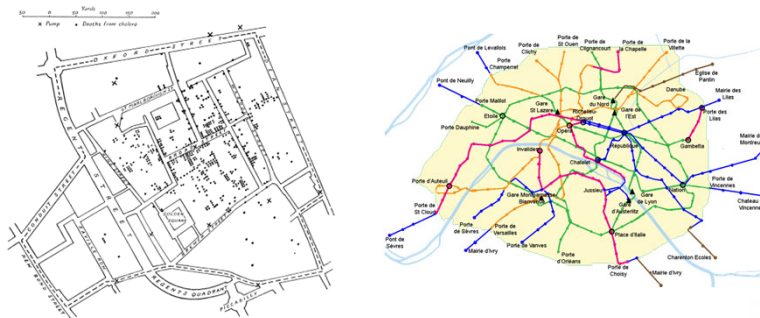
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Brief history

- Cholera epidemic (Soho district, London, 1845)
- Metro map of Paris before 1949



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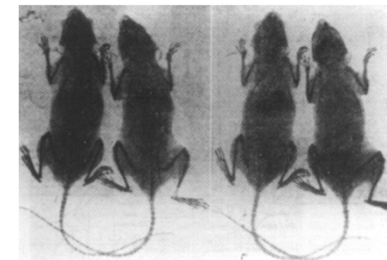
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Brief history

- X-rays (Wilhelm Conrad Röntgen, 1895)
- Stereo X-ray images (1896)



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Definition

- What is Scientific Visualization
 - Visualization is the process of representing abstract business or scientific data as images that can aid in understanding the meaning of the data
 - Visualization is any technique for creating images, diagrams, or animations to communicate a message. Visualization through visual imagery has been an effective way to communicate both abstract
 - Use of interactive graphic computing to visually represent abstract data to amplify cognition
- What it is not
 - Computer graphics focus in how to display the information to the end users. Very often computer graphics aim to create a eye-catching, stunning presentation in order to impress the audience, but usually this is not the primary goal of data analysis

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Definition

- So, in summary, what's the difference between graphics, rendering, and visualization?
 - Most people use all the terms interchangeably
 - In the visual effects and animation domain, the graphics and rendering are often used while in science and engineering, the term visualization is more commonly used
 - Graphics is used to describe the images generated from a computer, while rendering is about a 2D or 3D image created from an application, and finally, visualization is often used to describe a graphical representation of a 2D or 3D image

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Goals

- Compact graphical representation coupled with a user interface for:
 - Handle a large number of items ($10^2 - 10^{12}$)
 - Possibly extracted from DB
- Allowing users to
 - Explore, make discoveries
 - Make decisions, or
 - Find explanations
- On
 - Patterns (trends, groups, holes, isolated points)
 - Item groups
 - Individual items
- Visual data mining

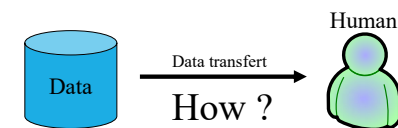
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General problem



- | | |
|--|--|
| <ul style="list-style-type: none"> ▪ Scientific data <ul style="list-style-type: none"> ▪ Density, pressure, speed, heat, ... ▪ List of ... ▪ Informations <ul style="list-style-type: none"> ▪ Quoted market price, ... ▪ Documents <ul style="list-style-type: none"> ▪ Web, books, articles, ... ▪ ... | <ul style="list-style-type: none"> ▪ Vision: 100 MB/s ▪ Hearing: <100 b/s ▪ Telepathy ▪ Haptic/tactile ▪ Smell ▪ Taste ▪ ... |
|--|--|

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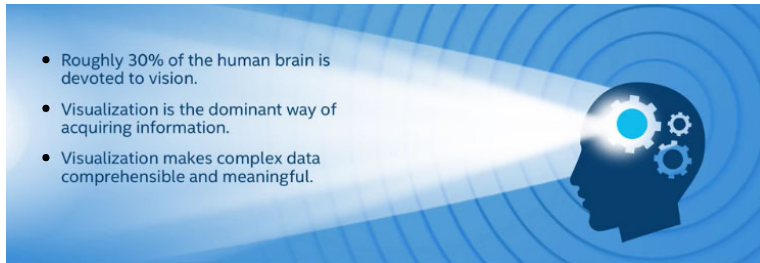
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General problem

- Visualization is foundational to insight



- Roughly 30% of the human brain is devoted to vision.
- Visualization is the dominant way of acquiring information.
- Visualization makes complex data comprehensible and meaningful.

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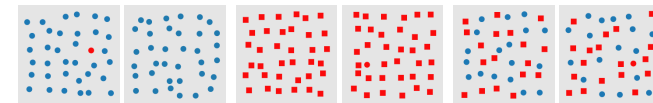


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Vision properties

- Meaning having the greatest bandwidth
- Fast and parallel
- Pattern recognition
- Pre-attentive (<http://www.csc.ncsu.edu/faculty/healey/PP/index.html>)
- Extend cognitive and memory skills

- We think visually, use it!



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Visual variables

	Points	Lines	Areas	Best to show
Shape		possible, but too weird to show	cartogram	qualitative differences
Size			cartogram	quantitative differences
Color Hue				qualitative differences
Color Value				quantitative differences
Color Intensity				qualitative differences
Texture				qualitative & quantitative differences

	area	line	point
size			
value			
hue			
saturation			
orientation			
shape			
arrangement			
texture			
focus			

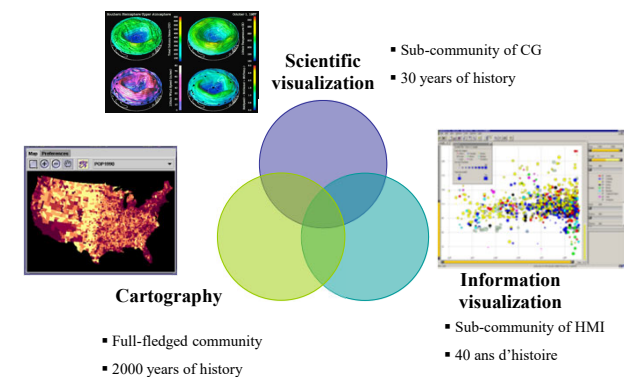
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Three fields



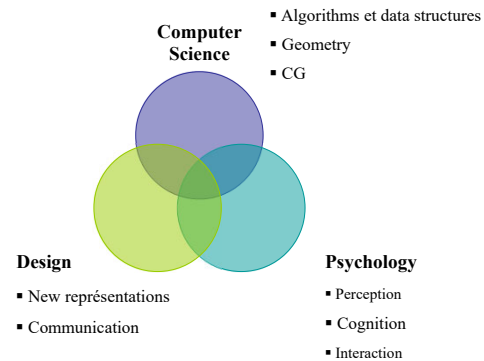
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Three subjects



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SciVis vs. InfoVis

- Scientific visualization (SciVis)
 - Representation of physical data
 - Spatialization is given by the underlying phenomenon
 - Is not non-informative
- Information visualization (InfoVis)
 - Representation of abstract data
 - Generally no canonical representation
 - Spatialisation is chosen
 - Is not unscientific

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OK but, SciVis or InfoVis ?

- Scientific, but not necessarily physics-based
 - Bioinformatic
 - Mathematical equations:
e.g., $f(i, j, k, w) = i^2 + j^2 + k^2 + w^2$
- Based on physics, but not necessarily scientific
 - Air traffic control systems
 - Cartography

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What kind of data ?

- Various types of data
 - Scalar field (temperature, pressure, ...)
 - Vector field (speed, orientation, ...)
 - Tensor field (mechanical stresses, curvature, ...)
- Problems of representation
 - Complex data (tensors, ...)
 - Data too numerous (multidimensionality, ...)
 - Noisy data
- Do we define the data on a surface, a volume (dimensionality of the domain)?

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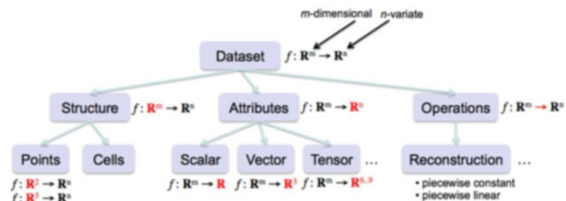
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Dataset

- Simple example: visualization of a scalar function of two variables
 - Assume we have a function $f: D \rightarrow \mathbb{R}$ defined on $D = X \times Y$ of two compact intervals $X \subset \mathbb{R}$ and $Y \subset \mathbb{R}$ and $f(x, y) = z$
 - The graph of the function is a 3D surface $S \subset \mathbb{R}^3$. Drawing the surface S can be viewed as warping, or elevating, every point $(x, y) \in X \times Y$ to a height $z = f(x, y)$ above the xy plane
 - Since we need a finite algorithm, we use a set of sample points from the domain D

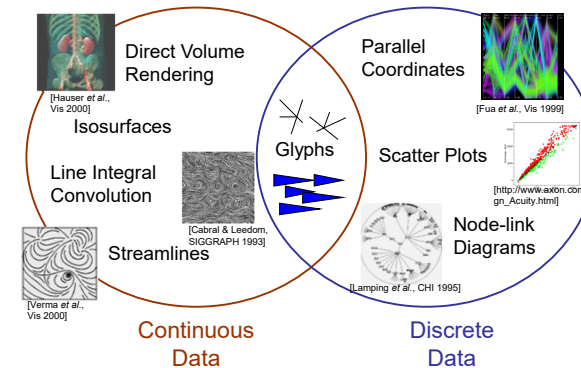


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Data taxonomy



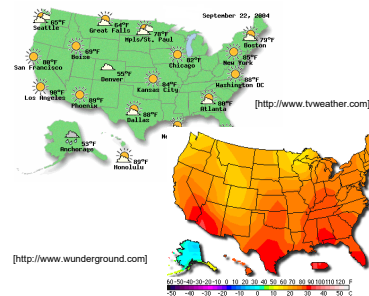
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Data taxonomy

- Mais...
- Une même donnée peut être visualisée de manière discrète ou continue



- Donc, notre interprétation des données est plus importante que les caractéristiques des données

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Taxonomie : modèle vs. donnée

- Nous classons les techniques de visualisation comme fondées sur l'hypothèse faite au sujet des données, e.g. : temperature:
 - Distributions (continue & quantitative)
 - Chaud, tiède, froid (ordinaire)
 - Brûlé vs. non brûlé (nominale)

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Taxonomie : modèle vs. donnée

- Data – échantillons du phénomène d'intérêt
 - Valeurs numériques stockées dans un fichier
- Design model – hypothèses de l'algorithme de visualisation adaptées aux données
 - Construit dans l'algorithme par le programmeur
- User model – idées de l'utilisateur et l'interprétation de ce que les données représentent
 - Dans l'esprit de l'utilisateur

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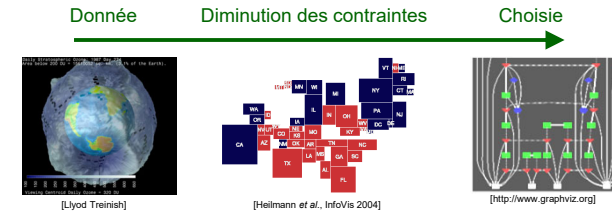
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Taxonomie : spatialisation

- Les techniques de visualisation peuvent être classées selon que la distribution spatiale est donnée ou choisie
- On étend cette idée à un continuum



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Taxonomie : spatialisation

	Donnée	Contrainte	Choisie
Continue	Medical images Fluid flow GIS distributions	Distorted given/continuous Arrangement of variable values	Continuous math functions Continuous temporal data
Discrete	Segmented images Air traffic positions GIS entities	Distorted given/discrete Arrangement of variable values	Discrete temporal data Arbitrary entity-relationship or multi-dimensional data

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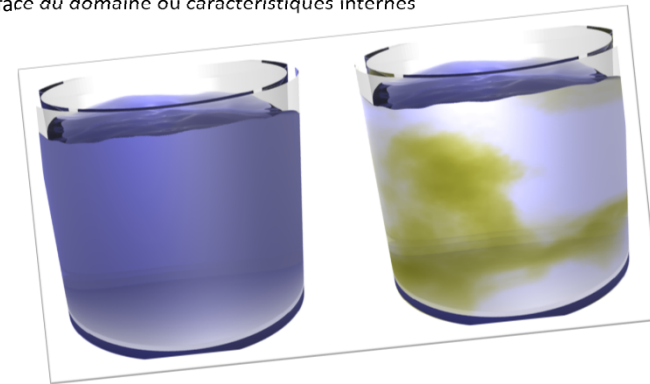
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Exemple: champ scalaire

- Surface du domaine ou caractéristiques internes



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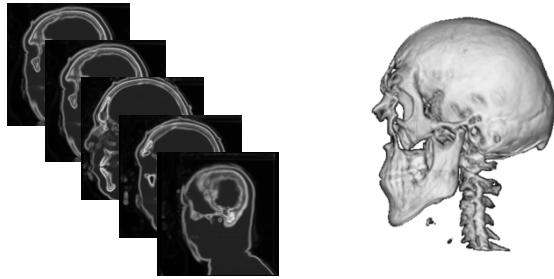
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Exemple: champ scalaire

- Section 2D ou vue volumique (isosurface, textures volumiques, ...)



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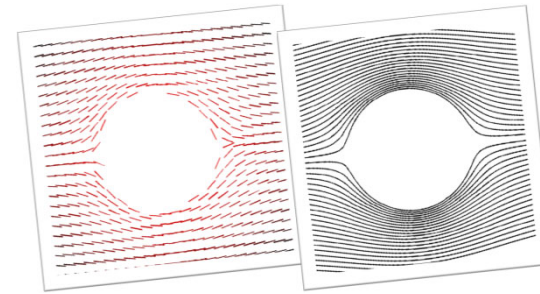
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Exemple: champ vectoriel

- Vecteurs ou trajectoires



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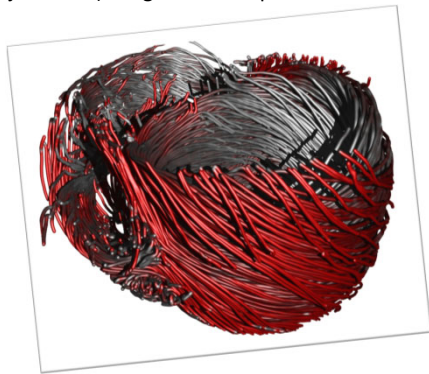
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Exemple: champ vectoriel

- Vecteurs ou trajectoires (les lignes de flux peuvent être un objet réel)



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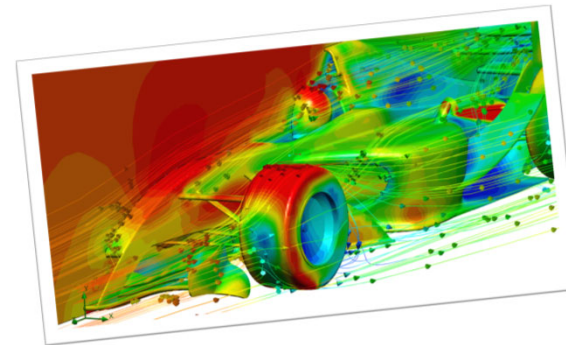
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Exemple: champ vectoriel

- Simulations physiques complexes (streamlines, ...)



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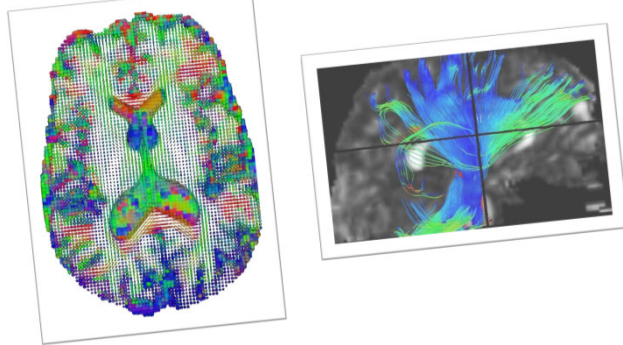
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Exemple : champ tensoriel

- Ellipsoïdes, glyphes, fiber-tracking, ...



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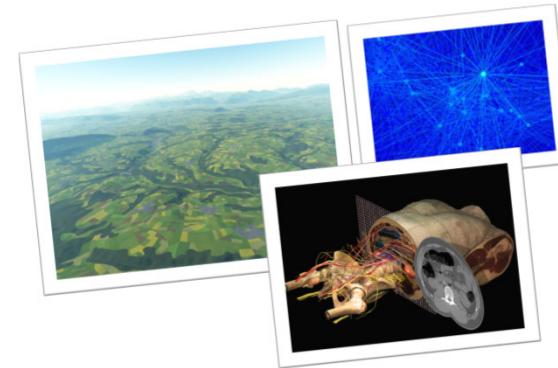
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Exemple : grands ensembles de données

- Données cartographiques, réseaux, ...



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Difficultés

- Nécessité d'une approche multirésolution
 - Affichage progressif
 - Transmission progressive
 - Niveau de détails (LOD)
 - Contrôle et édition hiérarchique
- Nécessité d'une approche Out-of-core

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Visualization Process Summary

- The primary goal of visualization is insight
- A picture is worth not just 1000 words, but potentially tera- or peta-bytes of data
- Larger datasets demand not just visualization, but advanced visualization resources and techniques
- Visualization system technology leverages lots of advancing technologies: GPUs, high-speed networks, web technology....
- Visualization software takes time to adapt

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