COSC 6344 Visualization

Fall 2023

University of Houston

Instructor: Guoning Chen
gchen22@central.uh.edu

Course Information (I)

- **Format:** **Face-to-Face ONLY (no live streaming or recording).**

- **Classroom:** CBB 118
- **Lecture Time:** 1~2:30PM Tu/Th
- **Office Hours**: 2:30~4PM Thursday after the class ***PGH 566***
- **Course webpage**: http://www2.cs.uh.edu/~chengu/Teaching/Fall2023/COSC6344_Visualization_Fall2023.html
- **TA:** Nguyen Phan (email: nguyenpkk95@gmail.com)

Course Information (II)

- **Prerequisites**:
  - *Knowledge and experience in **Python is required**, **knowledge of VTK is optional but a plus**
  - Knowledge on data structure and algorithm design
  - Knowledge on linear algebra, calculus, geometry
  - Experience on computer graphics is a plus but not required

- **Textbook:** (recommended, NOT required)
  - Alexandru C. Telea. **Data Visualization: Principles and Practice**, Second Edition, A.K.Peters, 2014 (Highly recommended)

  - Riccardo Mazza, **Introduction to Information Visualization**. Springer, 2009
  - Cole Nussbaumer Knaflic, **Storytelling with Data**. Wiley, 2015
  - Andy Kirk, Data Visualisation - A handbook for data driven design, SAGE, 2016

  - **Reading materials and course notes given in class or on course page**

Course Information (III)

- **Grading (tentative):**
  - 5 assignments (**20%**)
  - 2 exams (**40%**)
  - **In-class** quizzes (**15%**)
  - 1 final project and presentation (**25%**)

  *Grading scale (**tentative**): A: >92%; A-: >88%; B+: >84%; B: >80%; B-: >74%; C+: >68%; C: > 60%;*

- **Excused Absence Policy:**
  - Graduate Excused Absence Policy
  - Any excuses should be sent to the instructor BEFORE the class.

Course Information (IV)

- **Class rules:**
  - **Late Submission Policy:** Late assignments will be marked off 20% for each weekday that it is late. Submissions made 5 days after the deadline will not be accepted unless due to causes out of control of the students.
  - **Makeup policy:** There are NO make-up quizzes since the lowest three quiz scores will be dropped. There are no make-up assignments or exams unless an acceptable excuse is provided BEFORE the due date of the assignments or the time of the exam. Please refer to the excused absence policy below for more details.
  - **All exams and quizzes will take place in person during classes**. No remote exams and quizzes will be administered. We will use CASA Monitor during the exams to capture your screen activities. Please test CASA Monitor using the following link

    https://www.estudy.uh.edu/CASAMonitorLogin/Home/Test

Course Schedule (tentative)

TIMELINE	TOPICS
WEEK 1 (08/22, 24)	Class introduction, Visualization pipeline; Data type and data representation
WEEK 2 (08/29, 09/01)	Visual perceptions; Colors in visualization
WEEK 3 (09/05, 07)	VTK introduction; 2D scalar field visualization - color plots and iso-contouring (Assignment 1 out)
WEEK 4 (09/12, 14)	3D vector field visualization - Iso-surfacing; Direct volume rendering (DVR) – Ray casting (Assignment 2 out)
WEEK 5 (09/19, 21)	DVR- Splatting and texture-based; Transfer function design;
WEEK 6 (09/26, 28)	**Exam 1**; 2D vector field visualization – streamlines (Assignment 3 out)
WEEK 7 (10/03, 05)	2D vector field visualization - texture-based; Final project introduction
WEEK 8 (10/10, 12)	feature-based visualization for vector fields;
WEEK 9 (10/17, 19)	3D vector field visualization (Assignment 4 out); Unsteady flow visualization;
WEEK 10 (10/24, 26)	Tensor field visualization – overview; Tensor field visualization – Geometric-based and texture-based methods;
WEEK 11 (10/31, 11/02)	Tensor field visualization - Glyph-based technique; Information visualization – elementary plotting (Assignment 5 out);
WEEK 12 (11/07, 09)	Information visualization – graph and hierarchy data visualization
WEEK 13 (11/14, 16)	Review; **Exam 2**;
WEEK 14 (11/21, 23)	Information visualization – high dimensional data visualization; Thanksgiving holiday (no class)
WEEK 15 (11/28, 11/30)	Final project presentations

Additional Information

- **Honor Code Statement:**
  - Students may be asked to sign an honor code statement as part of their submission of any graded work including but not limited to projects, quizzes, and exams: *"I understand and agree to abide by the provisions in the University of Houston Graduate Academic Honesty Policy. I understand that academic honesty is taken very seriously, and, in the cases of violations, penalties may include suspension or expulsion from the University of Houston."*

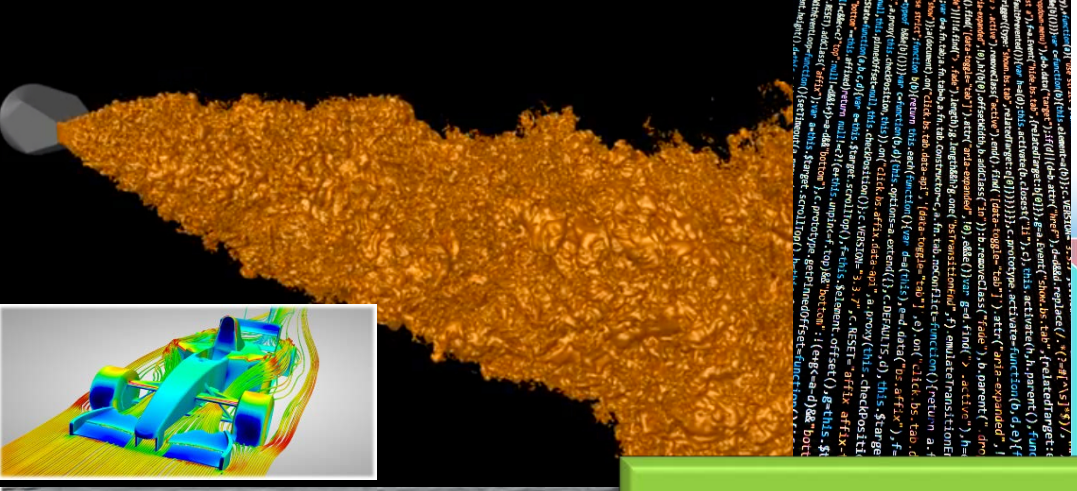
- **Recording of Class:**
  - Students may not record all or part of class, livestream all or part of class, or make/distribute screen captures, without advanced written consent of the instructor or the agreement for special accommodation.

- **Syllabus Changes:**
  - Due to the changing nature of the COVID-19 pandemic, please note that the instructor may need to make modifications to the course syllabus and may do so at any time. Notice of such changes will be announced as quickly as possible through class emails, in-class lecture, Teams messages, and Blackboard announcements.

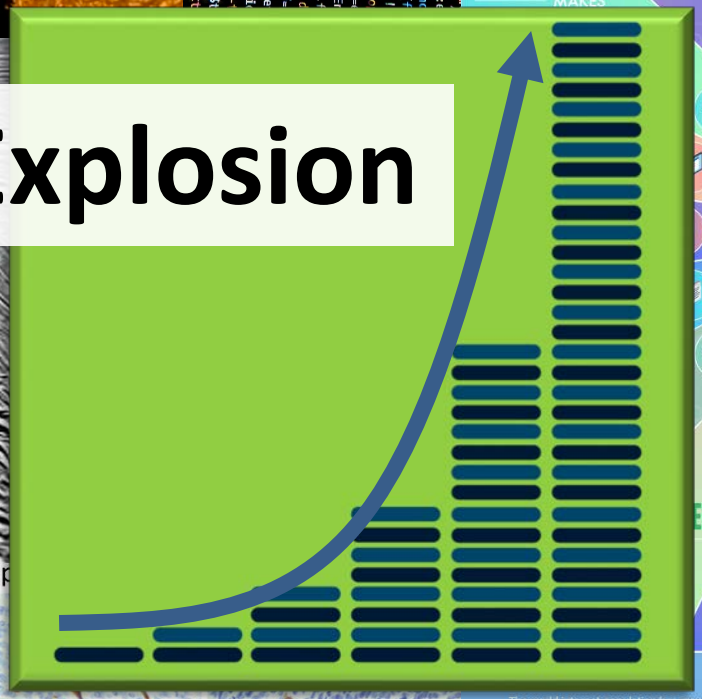
Questions?

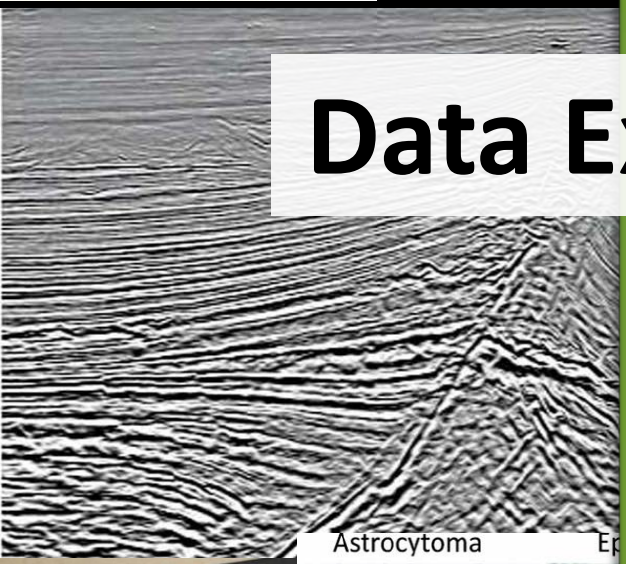
Background

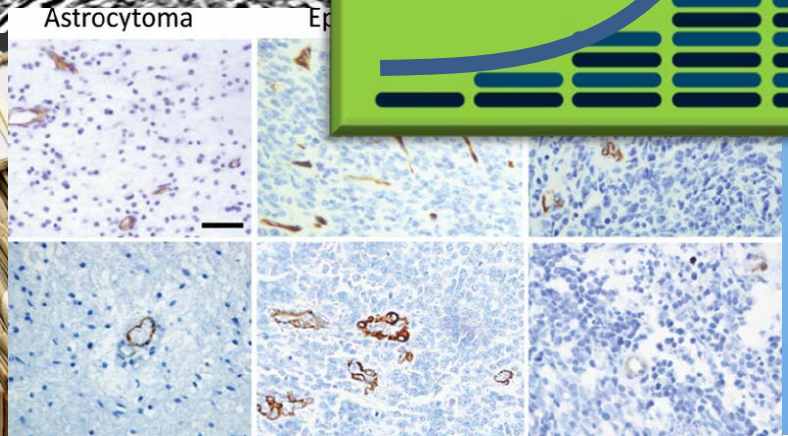
Goal: Through this lecture, you should know
(1) why visualization is important
(2) what is modern visualization and what it can do
(3) differences between scientific data and information data

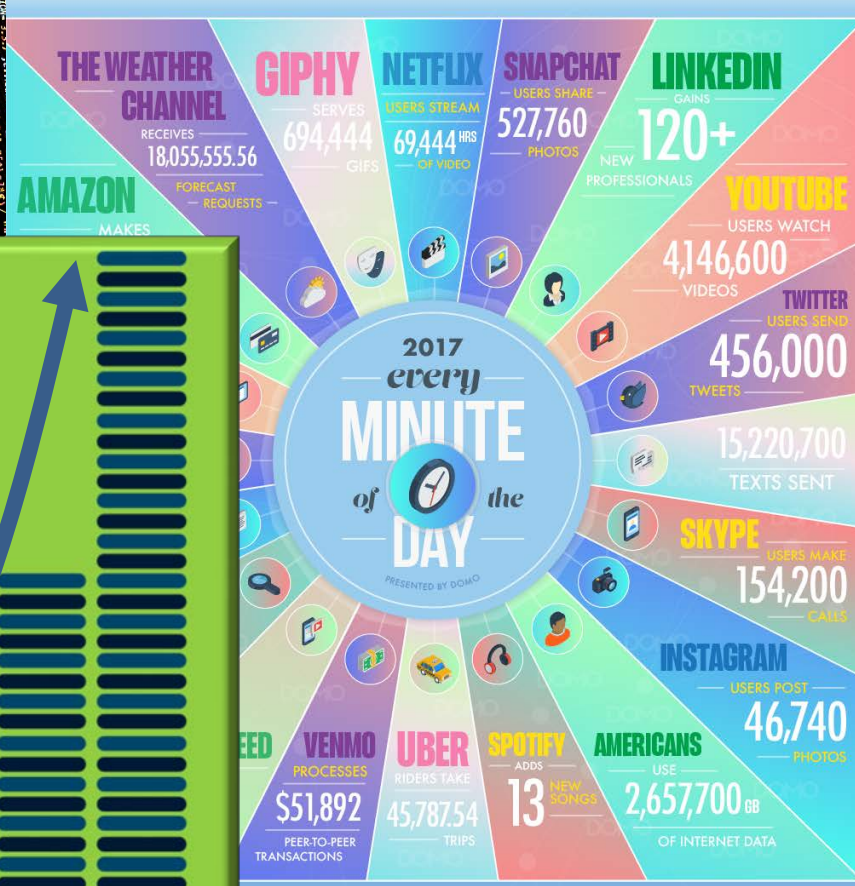


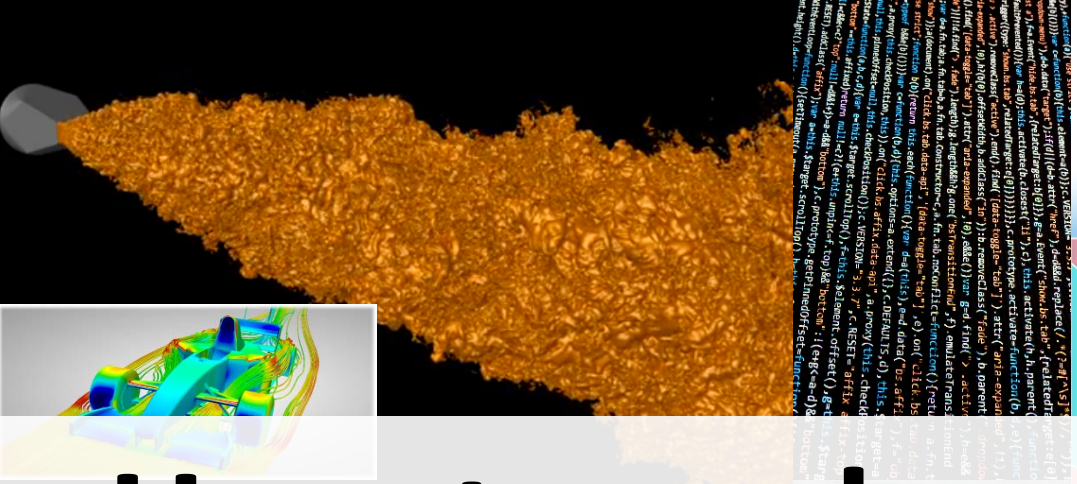
Data Explosion



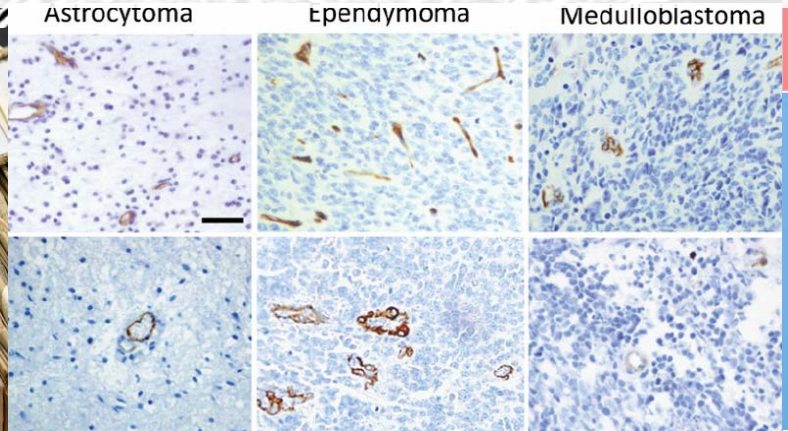








How to make use of them for knowledge discovery and decision making?



Data Mining

Data mining is the process of discovering patterns and knowledge in large data sets involving methods at the intersection of machine learning, statistics, and database systems.

From Wikipedia

- groups of data records (cluster analysis)
- unusual records (anomaly detection)
- dependencies (association rule mining, sequential pattern mining)

Data Mining or **Visualization?**

Visualization is suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods.

Let us start with a simple example

29, 31, 37, 41, 23, 43, 47, 19, 53, 17, 59, 61, 67, 71, 73, 13, 79, 83, 89, 11, 97, 101, 103, 107, 109, 113, 127, 131, 137, 139, 7, 149, 151, 157, 163, 167, 173, 49, 179, 181, 121, 191, 193, 197, 199, 5, 211, 25, 169, 223, 227, 229, 233, 239, 241, 990, 251, 143, 257, 91, 77, 263, 119, 133, 269, 271, 125, 187, 277, 161, 281, 283, 960, 209, 966, 85, 95, 65, 221, 930, 293, 115, 924, 55, 203, 145, 307, 247, 155, 311, 217, 289, 313, 900, 840, 253, 317, 870, 185, 35, 984, 996, 331, 936, 3, 205, 9, 882, 337, 259, 978, 215, 27, 858, 954, 972, 918, 299, 347, 948, 912, 349, 910, 980, 235, 942, 353, 287, 810, 780, 359, 81, 323, 319, 798, 906, 888, 301, 265, 367, 894, 876, 373, 361, 175, 341, 379, 864, 846, 852, 69, 87, 93, 295, 816, 828, 57, 329, 383, 111, 750, 51, 792, 123, 343, 129, 305, 834, 389, 141, 756, 950, 822, 39, 159, 804, 880, 275, 397, 720, 770, 177, 33, 714, 1000, 183, 401, 920, 970, 377, 786, 245, 335, 774, 940, 201, 690, 409, 213, 117, 153, 219, 371, 726, 768, 391, 762, 952, 171, 850, 99, 243, 744, 237, 325, 355, 738, 660, 207, 419, 890, 249, 732, 421, 365, 702, 860, 403, 994, 267, 672, 407, 708, 630, 696, 820, 21, 261, 431, 830, 938, 684, 291, 433, 279, 303, 63, 700, 760, 868, 309, 988, 395, 413, 439, 790, 678, 800, 321, 666, 443, 896, 327, 854, 812, 740, 339, 437, 654, 826, 147, 427, 449, 884, 333, 946, 415, 648, 624, 642, 728, 730, 636, 836, 962, 600, 902, 189, 680, 986, 297, 710, 457, 968, 612, 784, 369, 618, 650, 381, 451, 461, 742, 425, 588, 945, 463, 594, 748, 606, 670, 814, 351, 393, 874, 387, 570, 467, 806, 15, 445, 45, 363, 385, 411, 75, 582, 640, 754, 782, 417, 620, 686, 616, 644, 658, 832, 576, 135, 423, 610, 469, 473, 546, 564, 682, 479, 558, 590, 735, 560, 704, 225, 447, 540, 552, 580, 638, 602, 646, 453, 481, 992, 928, 550, 676, 273, 475, 487, 574, 357, 455, 572, 598, 722, 231, 459, 528, 534, 471, 736, 825, 399, 429, 441, 485, 491, 375, 477, 522, 944, 976, 493, 530, 532, 848, 975, 405, 520, 608, 510, 516, 578, 752, 489, 656, 688, 904, 345, 497, 518, 544, 776, 808, 824, 856, 872, 285, 483, 504, 525, 592, 632, 664, 712, 844, 892, 908, 916, 932, 956, 964, 255, 435, 499, 506, 536, 568, 584, 585, 596, 604, 628, 652, 668, 674, 692, 694, 698, 706, 716, 718, 724, 734, 746, 758, 764, 766, 772, 778, 788, 794, 796, 802, 818, 838, 842, 862, 866, 878, 886, 898, 914, 922, 926, 934, 958, 974, 982, 998, 2, 4, 8, 16, 32, 64, 128, 256, 422, 446, 452, 454, 458, 465, 466, 472, 478, 482, 488, 494, 495, 496, 500, 501, 502, 508, 512, 514, 524, 526, 538, 542, 548, 554, 556, 562, 566, 586, 614, 622, 626, 634, 662, 298, 302, 314, 326, 334, 346, 358, 362, 382, 386, 388, 394, 398, 404, 412, 424, 428, 436, 464, 484, 498, 507, 765, 226, 254, 262, 274, 278, 316, 332, 356, 503, 555, 194, 202, 206, 214, 218, 268, 284, 292, 376, 490, 492, 505, 513, 158, 166, 178, 236, 244, 328, 344, 476, 855, 134, 142, 146, 195, 212, 486, 615, 118, 122, 296, 368, 416, 519, 106, 188, 442, 448, 470, 511, 561, 645, 693, 164, 172, 248, 509, 94, 232, 474, 515, 531, 567, 705, 82, 86, 148, 165, 304, 460, 480, 418, 434, 609, 74, 124, 338, 468, 537, 675, 116, 272, 352, 517, 62, 184, 543, 795, 58, 392, 549, 315, 406, 430, 440, 456, 651, 374, 819, 92, 152, 462, 627, 885, 46, 400, 410, 444, 521, 136, 535, 539, 915, 76, 208, 438, 523, 527, 242, 432, 38, 450, 573, 68, 663, 426, 529, 533, 579, 34, 545, 595, 364, 176, 370, 380, 104, 591, 777, 322, 414, 597, 603, 621, 52, 105, 286, 402, 408, 26, 320, 553, 88, 565, 224, 340, 384, 741, 541, 575, 44, 396, 759, 861, 308, 551, 22, 196, 266, 310, 633, 420, 639, 366, 372, 547, 350, 559, 605, 903, 290, 657, 665, 238, 250, 354, 378, 348, 112, 669, 390, 557, 581, 98, 987, 342, 324, 681, 200, 687, 260, 563, 56, 318, 230, 583, 699, 182, 360, 711, 28, 160, 569, 14, 280, 336, 571, 897, 288, 717, 306, 312, 715, 723, 589, 190, 625, 154, 220, 282, 577, 729, 957, 747, 635, 637, 100, 170, 783, 276, 753, 891, 80, 258, 623, 587, 294, 330, 771, 969, 246, 611, 50, 655, 40, 593, 264, 867, 300, 789, 216, 805, 20, 130, 801, 10, 222, 599, 837, 228, 601, 807, 234, 813, 192, 110, 252, 607, 629, 270, 831, 685, 204, 186, 613, 843, 140, 162, 849, 695, 174, 617, 649, 619, 144, 198, 873, 240, 725, 679, 879, 631, 909, 108, 138, 156, 671, 70, 96, 927, 921, 875, 641, 667, 114, 168, 643, 933, 72, 707, 745, 939, 132, 647, 102, 951, 963, 999, 54, 180, 755, 48, 775, 653, 689, 721, 981, 36, 210, 659, 24, 126, 661, 935, 18, 78, 993, 12, 150, 697, 845, 6, 785, 66, 703, 673, 749, 677, 84, 120, 713, 683, 763, 737, 815, 691, 90, 731, 847, 42, 835, 701, 791, 833, 60, 709, 865, 767, 719, 30, 781, 727, 733, 895, 779, 925, 739, 793, 803, 905, 743, 751, 799, 757, 761, 769, 931, 817, 955, 889, 773, 965, 787, 985, 917, 869, 995, 797, 851, 871, 809, 811, 841, 821, 959, 823, 827, 829, 913, 973, 893, 839, 901, 899, 923, 853, 857, 859, 863, 949, 877, 881, 979, 883, 943, 887, 907, 911, 919, 989, 929, 961, 937, 941, 947, 953, 967, 971, 977, 983, 991, 997, ,

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

can you tell me the trend of these numbers from left to right?

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

22-25	26-29	30-33
34-37	38-41	42-45

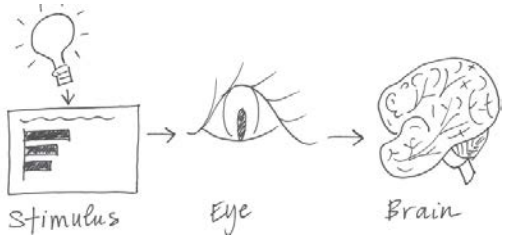
23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

22-25	26-29	30-33
34-37	38-41	42-45

What Does This Example Tell Us?

Visual representation is one effective way to convey information



Cognitive study has shown that human visual system is the most effective channel to transport information to the brain.

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

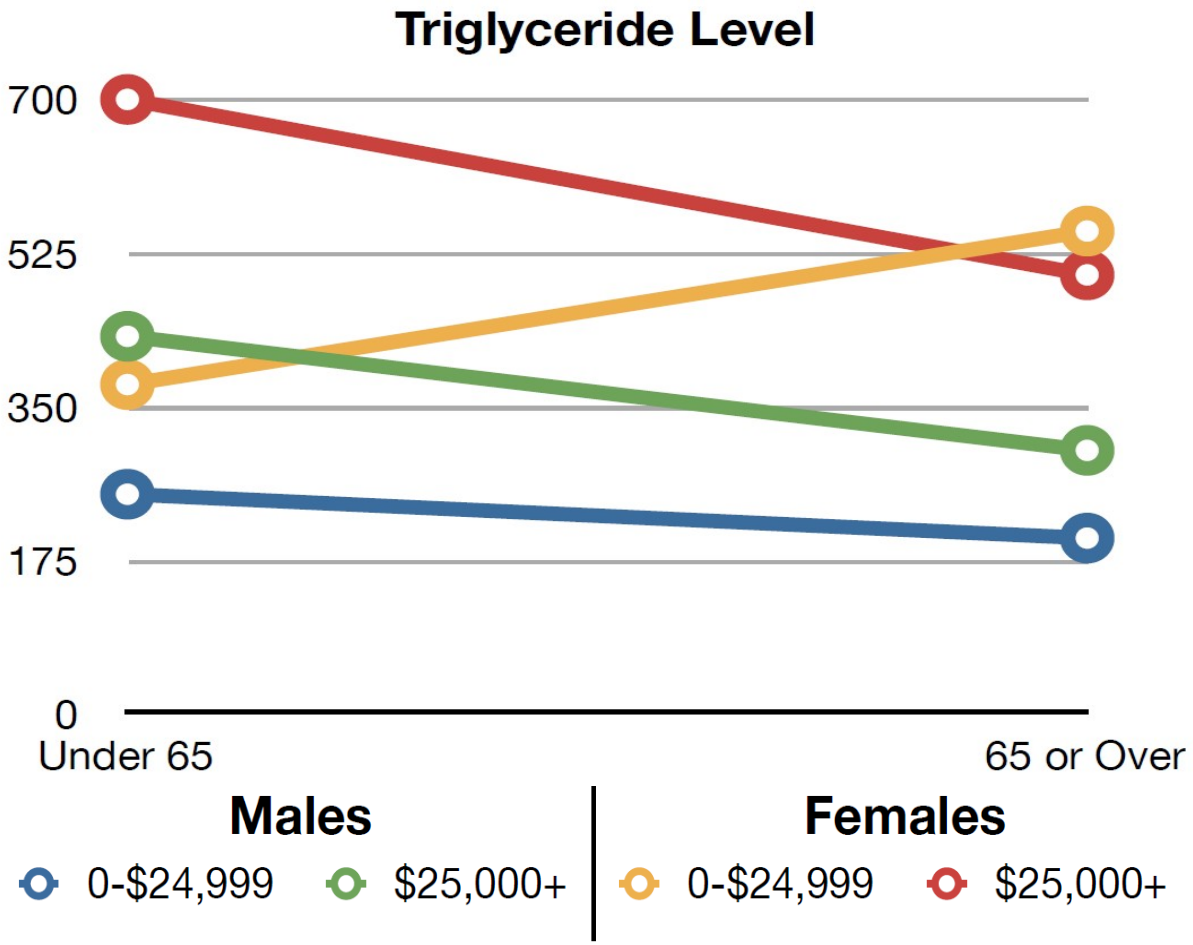
22-25	26-29	30-33
34-37	38-41	42-45

Leading to the introduction of **visualization**.

Which gender and income group of people has different trend of triglyceride (the percentage of fat) level over years from the others?

	Male		**Female**	
Income\Age	<65	65 and above	<65	65 and above
0-$24,999	250	200	375	550
$25,000+	430	300	700	500

How many groups?


Triglyceride Level
700
525
350
175
0
Under 65
65 or Over
Males
0-$24,999
$25,000+
Females
0-$24,999
$25,000+

History of Visualization

- Visualization is actually rather old

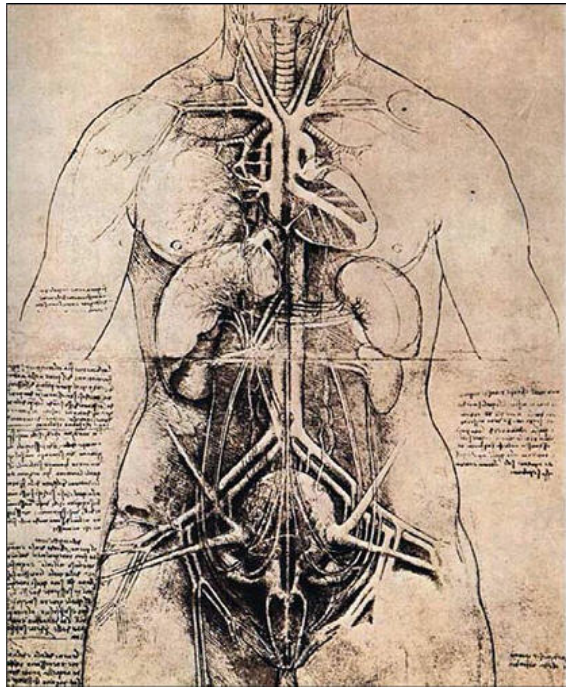
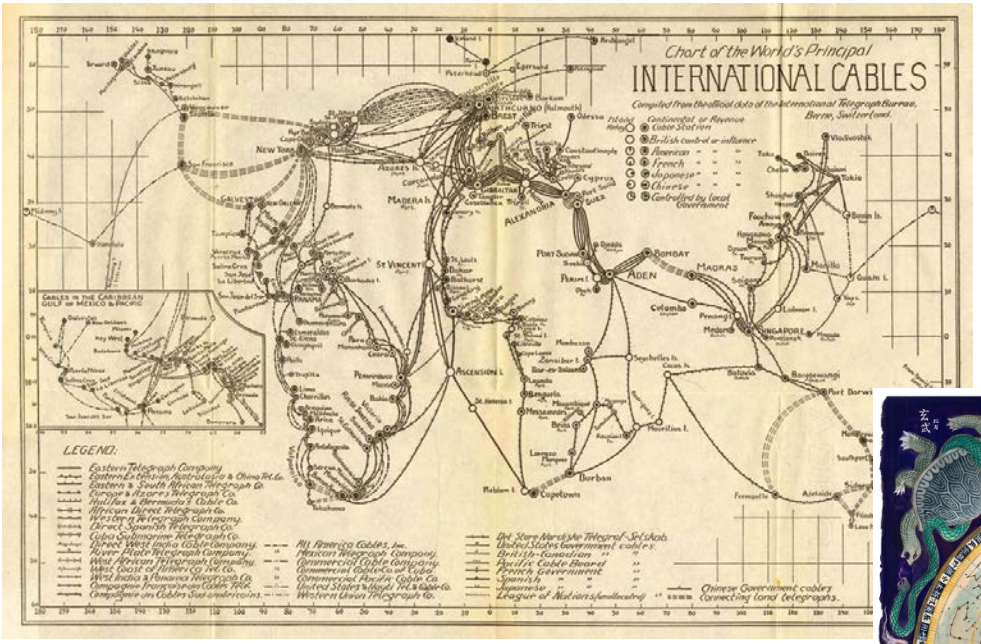


Image source: http://www.leonardo-da-vinci-biography.com/leonardo-da-vinci-anatomy.html



http://www.visualinformation.info/old-international-cables-map-year-1924/

- Often an intuitive step: graphical illustration

What is (Modern) Visualization?

- In 1987
  - the National Science Foundation (of the U.S.) started “Visualization in scientific computing” as a new discipline, and a panel of the ACM coined the term “scientific visualization”
  - Scientific visualization, briefly defined: *The use of computer graphics for the analysis and presentation of computed or measured scientific data*.

- Oxford Engl. Dict., 1989
  - to form a mental vision, image, or picture of (something not visible or present to the sight, or of an abstraction); to make visible to the mind or imagination

- Visualization transforms data into images that effectively and accurately represent information about the data.
  - Schroeder et al. The Visualization Toolkit, 2nd ed. 1998

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Tool/Means to enable a User **insights into Data** via **Visual Representation**

(**or an understanding of the story behind the data**)

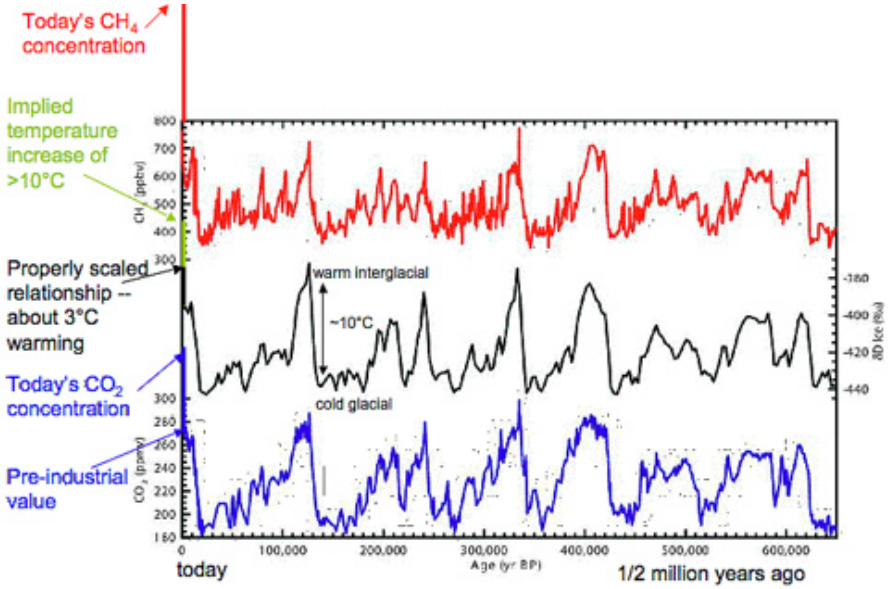
Why is Visualization Important?

- To effectively convey information to data stakeholders

Table 7-2 Direct global warming potentials of several well-mixed trace gases relative to CO_2. The GWPs of the various non-CO_2 species are calculated for each of five time horizons (20, 50, 100, 200 and 500 years) using, as in IPCC, the carbon cycle model of Siegenthaler (1983). (Note that IPCC contained a typographical error which led to incorrect values for the direct GWP of methane.)

Gas	Lifetime (years)	Time Horizons				
		20 years	50 years	100 years	200 years	500 years
CO_2	#	1	1	1	1	1
CH_4	10.5	35	19	11	7	4
N_2O	132	260	270	270	240	170
CFC-11	55	4500	4100	3400	2400	1400
CFC-12	116	7100	7400	7100	6200	4100
HCFC-22	15.8	4200	2600	1600	970	540
CFC-113	110	4600	4700	4500	3900	2500
CFC-114	220	6100	6700	7000	7000	5800
CFC-115	550	5500	6200	7000	7800	8500
HCFC-123	1.71	330	150	90	55	30
HCFC-124	6.9	1500	760	440	270	150
HFC-125	40.5	5200	4500	3400	2200	1200
HFC-134a	15.6	3100	1900	1200	730	400
HCFC-141b	10.8	1800	980	580	350	200
HCFC-142b	22.4	4000	2800	1800	1100	620
HFC-143a	64.2	4700	4500	3800	2800	1600
HFC-152a	1.8	530	250	150	89	49
CCl_4	47	1800	1600	1300	860	480
CH_3CCl_3	6.1	360	170	100	62	34
CF_3Br	77	5600	5500	4900	3800	2300

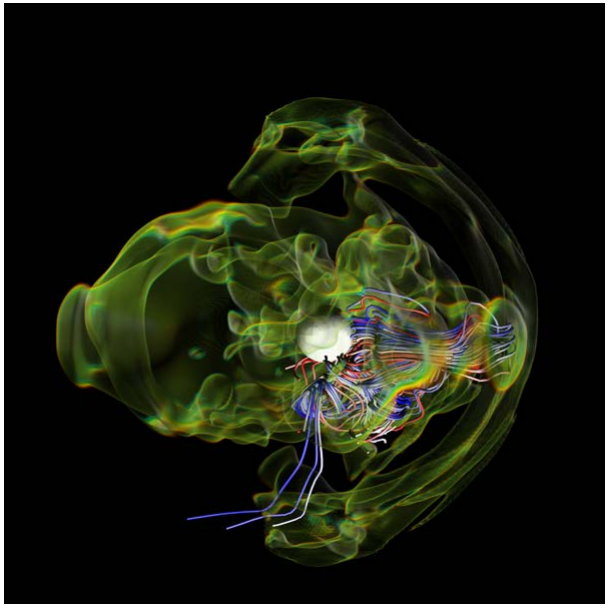
SAOD Table 7.2 (p. 7.6)



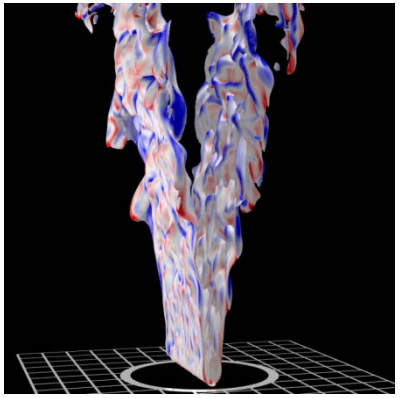
Methane, **temperature** (from hydrogen isotope ratios ("δD") and carbon dioxide from the Dome C Ice core. (EPICA Project members, 2006).

Why is Visualization Important?

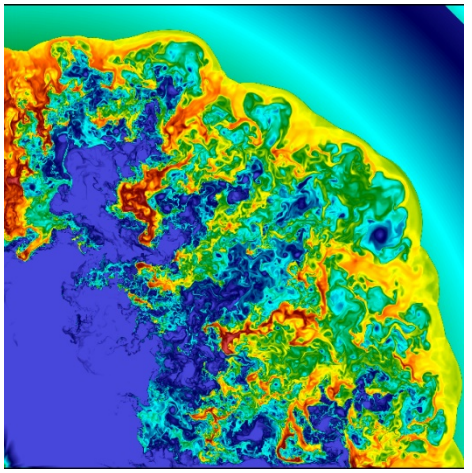
- To effectively convey information to data stakeholders
- To make invisible phenomena **visible**

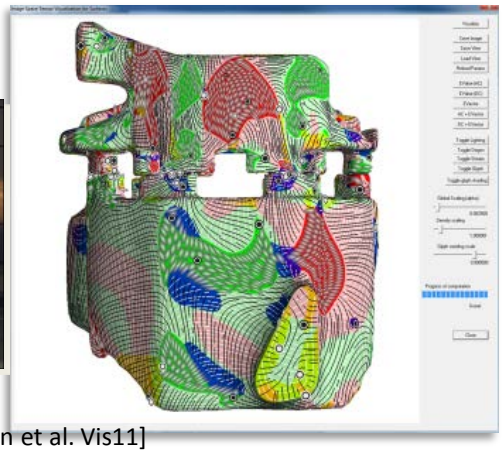


Astrophysics
source: VACET



Combustion
source: VACET



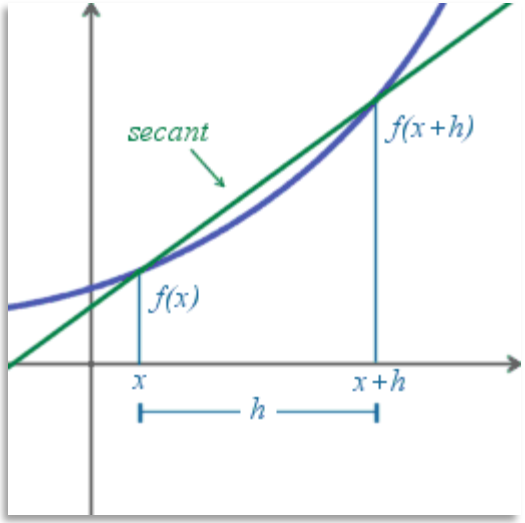


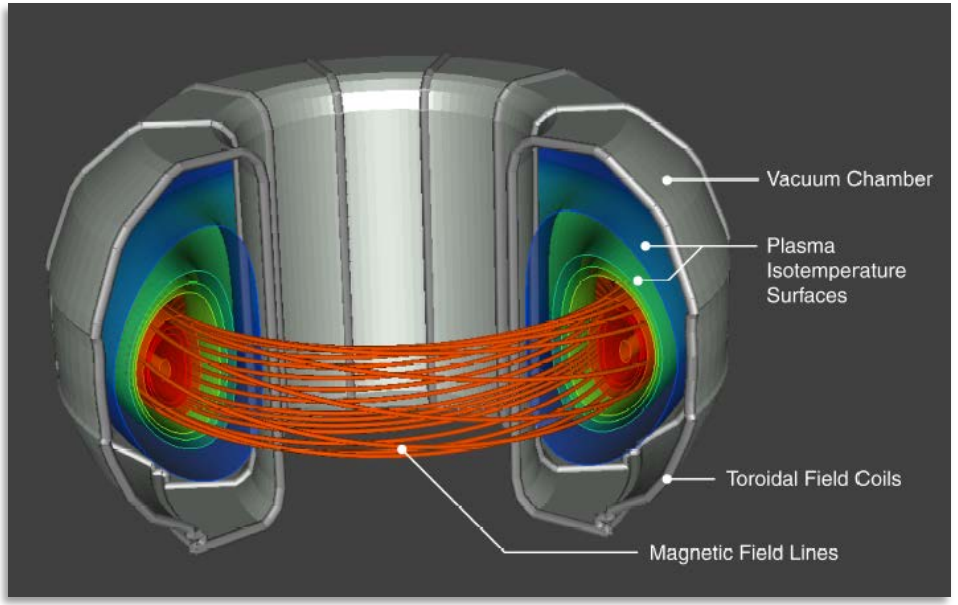
Automobile design [Chen et al. Vis11]

Why is Visualization Important?

- To effectively convey information to data stakeholders.
- To make invisible phenomena visible.
- Create intuitive representation for abstract concepts

$$\frac{dy}{dx} = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$$

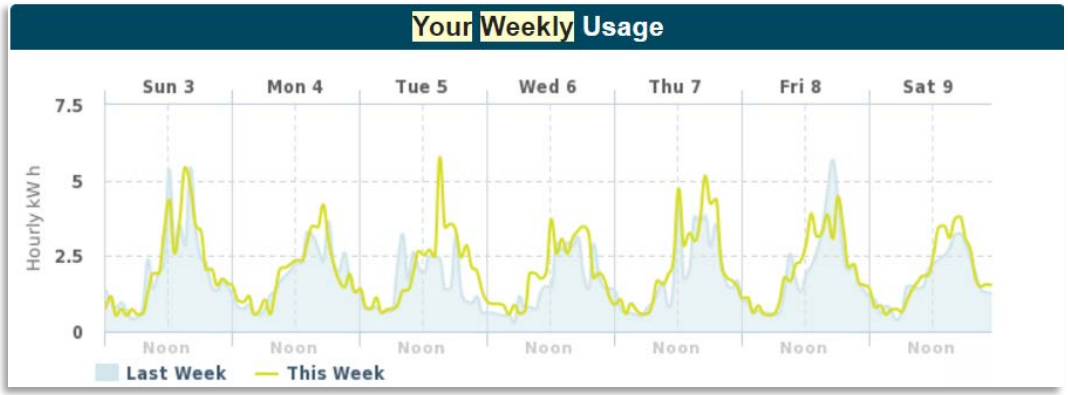




Fusion physics

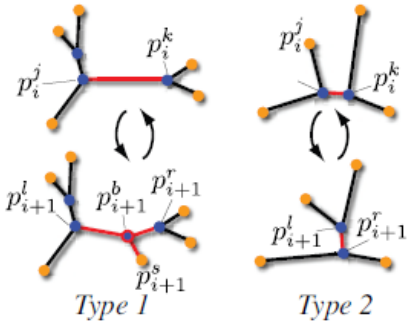
What Does Visualization Do?

- Three types of **goals** for visualization
  - … to **present**
    - "everything" known about the data,
    - Vis. used for **Communication of Results**



6.1. Topological Changes

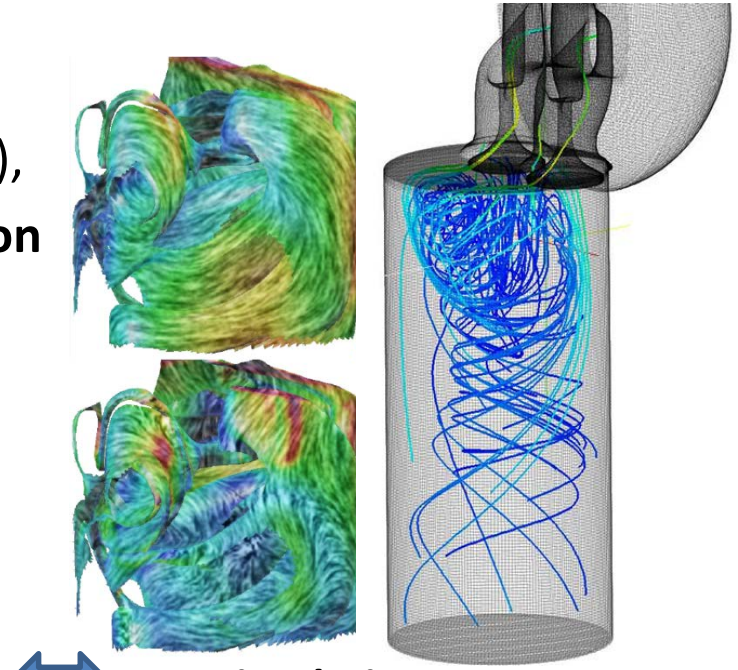
For smoothly changing geometry of the boundary, there are only two generic transitions of the mid-structures [GK03]: **Leaf creation/annihilation** (*Type 1*) and **Flip configuration** (*Type 2*). *Type 1* corresponds to the creation (or destruction) of a feature (e.g. a protrusion) on the boundary. To illustrate *Type 2*, consider the junction points, p_i^j and p_i^k in M_i and p_{i+1}^l and p_{i+1}^r in M_{i+1}, respectively. Each pair is connected by an edge. In the continuous case, edge (p_i^j, p_i^k) will first collapse into a single node before growing to edge (p_{i+1}^l, p_{i+1}^r). However, the discrete cutting will likely not capture the degenerate point as shown in the figure to the right.



What Does Visualization Do?

- Three types of goals for visualization
  - … to present
    - "everything" known about the data,
    - Vis. used for Communication of Results
  - … to **analyze**
    - There are hypotheses (expect to see…),
    - Vis. used for **Verification or Falsification**

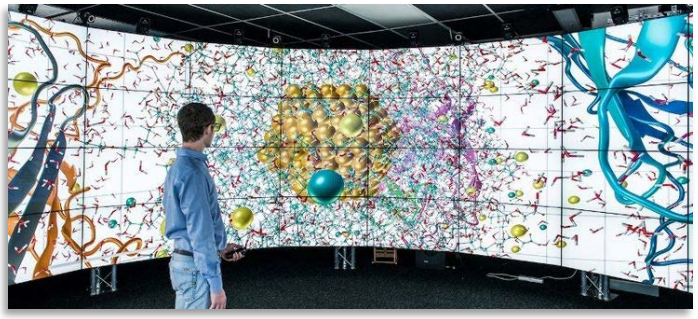
Hypothesis

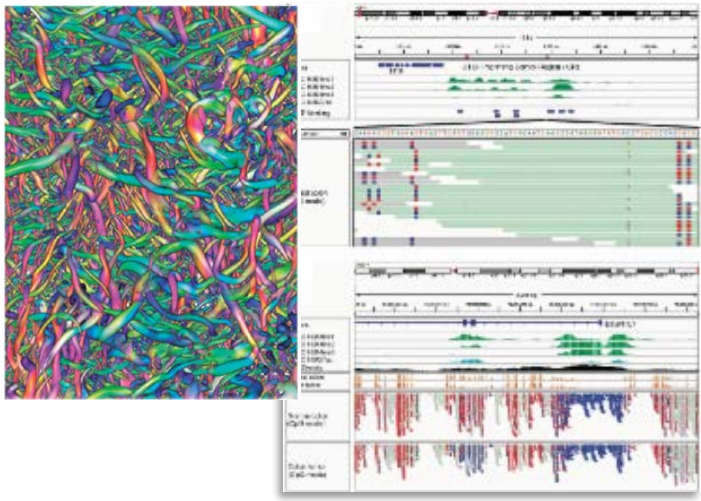


Simulations

What Does Visualization Do?

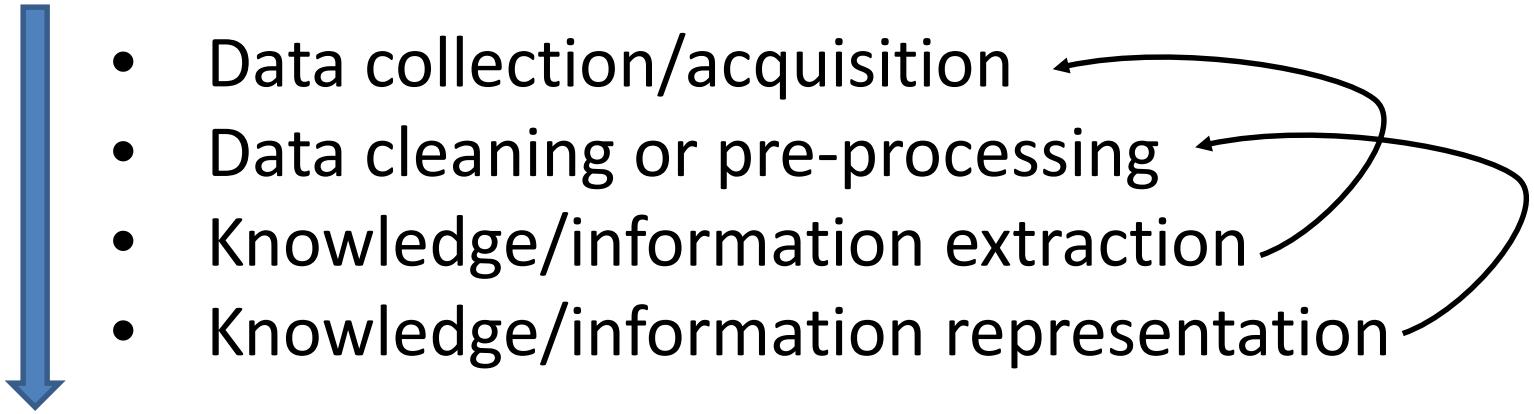
- Three types of goals for visualization
  - … to present
    - "everything" known about the data,
    - Vis. used for Communication of Results
  - … to analyze
    - There are hypotheses,
    - Vis. used for Verification or Falsification
  - … to **explore**
    - Nothing (or little) is known,
    - Vis. used for **data exploration/ knowledge discovery**





- This is a very rich and highly inter-disciplinary area that combines knowledge from various disciplines (including the **application areas** and many sub-fields in computer science).

What can visualization help with different stages of knowledge discovery?

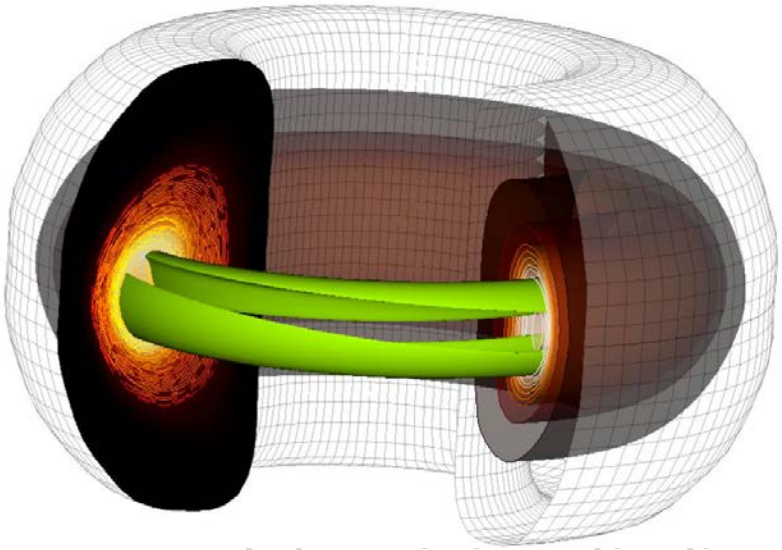


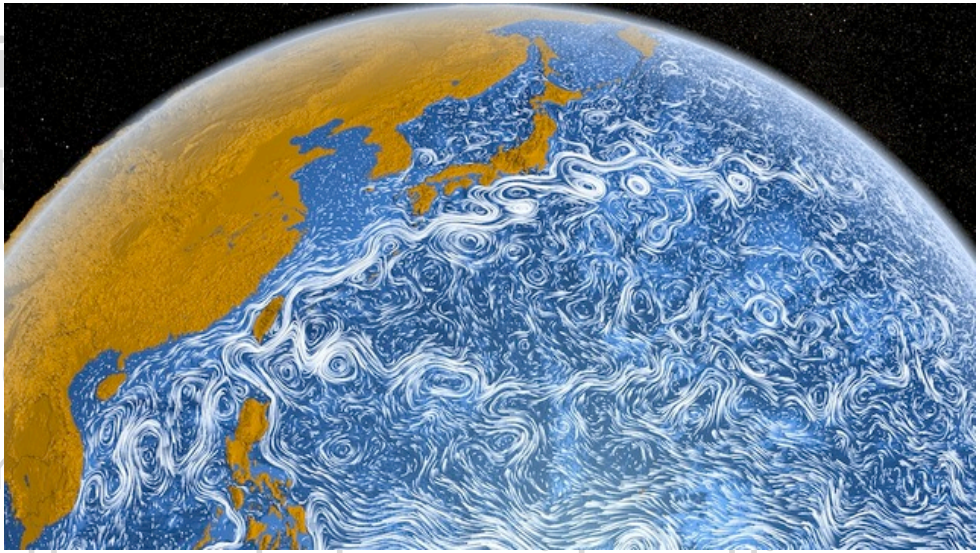
Types of Data and Their Visualizations

Goal: You should know the difference between the two basic types of data and be able to classify a data given to you.

SciVis vs. InfoVis

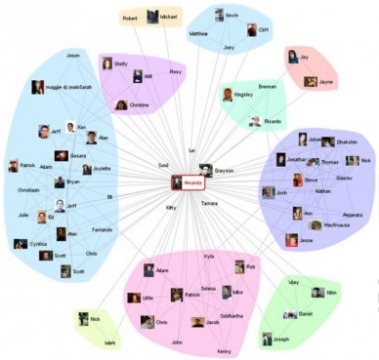
- Scientific visualization is mostly concerned with:
  - 2-, 3-, 4-dimensional (i.e., physical space+time) data
  - discretized or sampled data (for ***continuous*** function)

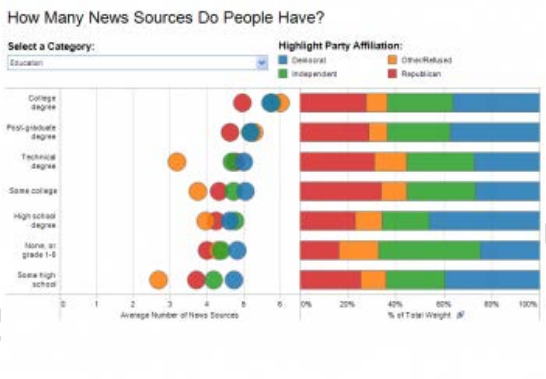


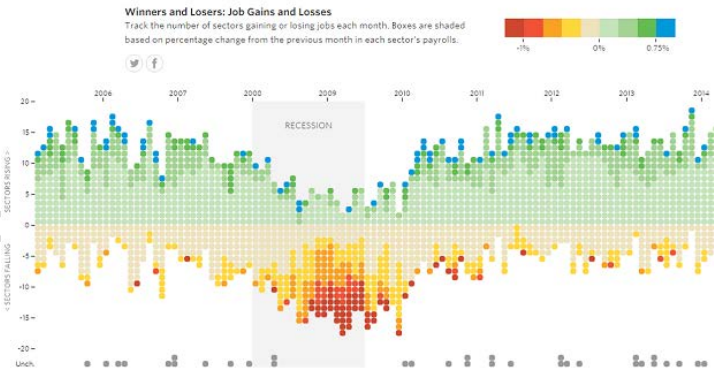


- data mining: finding patterns, clusters, voids, outliers

SciVis vs. **InfoVis**

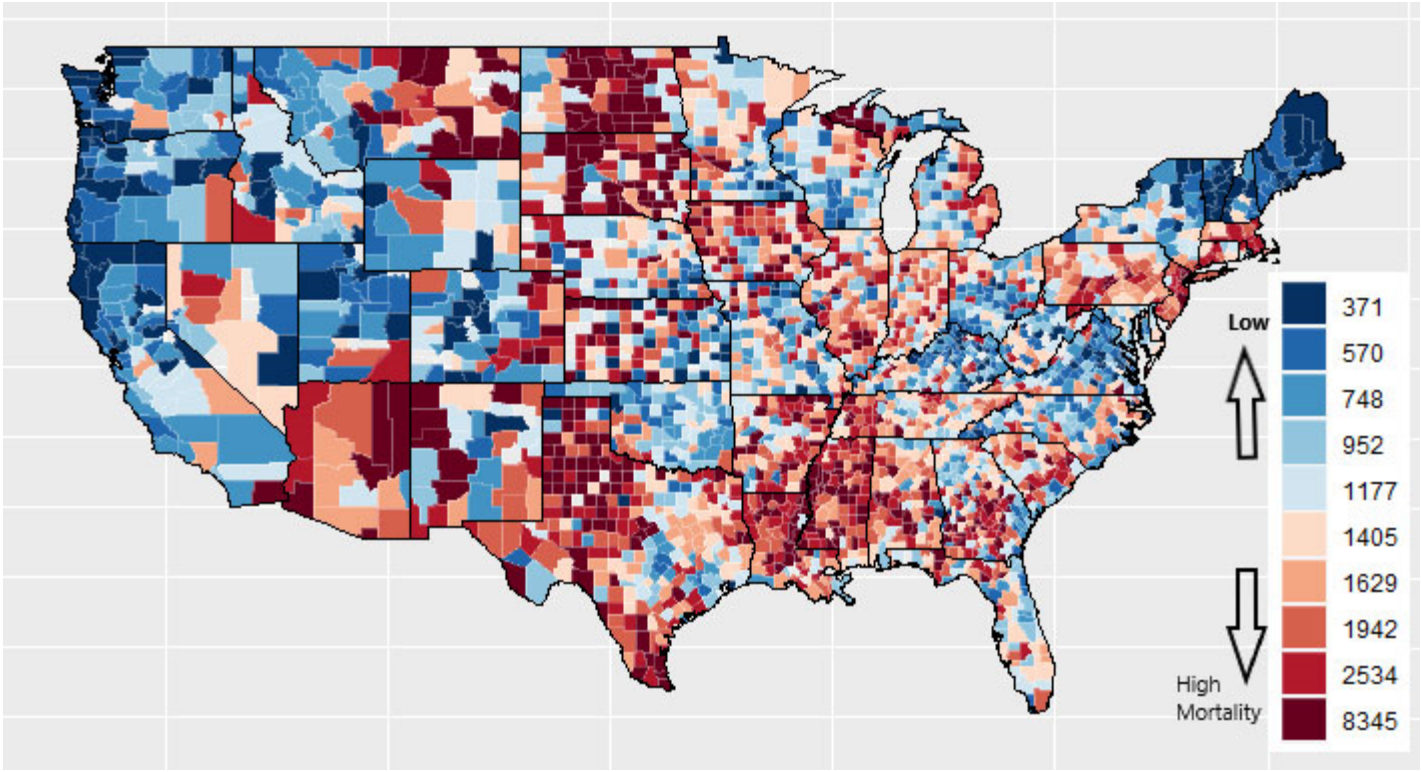






- Information visualization focuses on:
  - high-dimensional, ***abstract*** data (no natural (x,y,z) coordinates!)
  - **inherently *discrete*** data
    - financial, statistical, etc.
    - visualization of large trees, networks, graphs

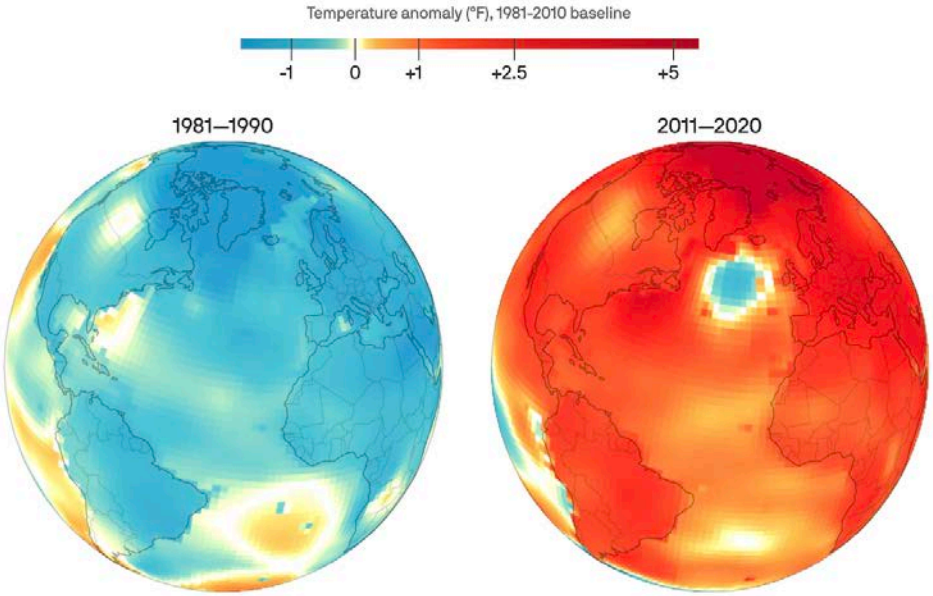
Example 1: SciVis or InfoVis?



COVID-19 Death Rates Vary Widely by County

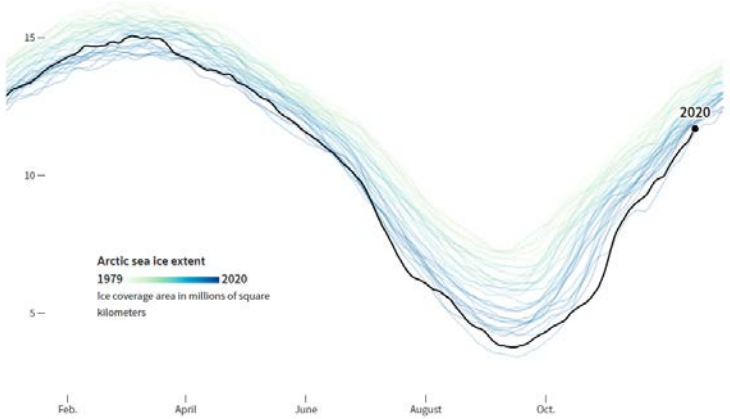
https://anderson-review.ucla.edu/covid-19-death-rates-vary-widely-by-county-but-why/

Example 2: SciVis or InfoVis?



the graphic shows that annual temperatures in South America were two degrees hotter in 2020 than in 1981

https://datainnovation.org/2021/07/visualizing-global-climate-change/



https://www.anychart.com/blog/2021/01/15/climate-change-data-visualizations/

Global Climate Change

Goals and Topics

Goals of this Course

- Know the types of visualization problems! Does it belong to scientific visualization, information visualization or their combination?

- Know the representative/standard methods for visualizing some common data forms.

- Be able to develop the customized visualization techniques and systems for practical and research needs.

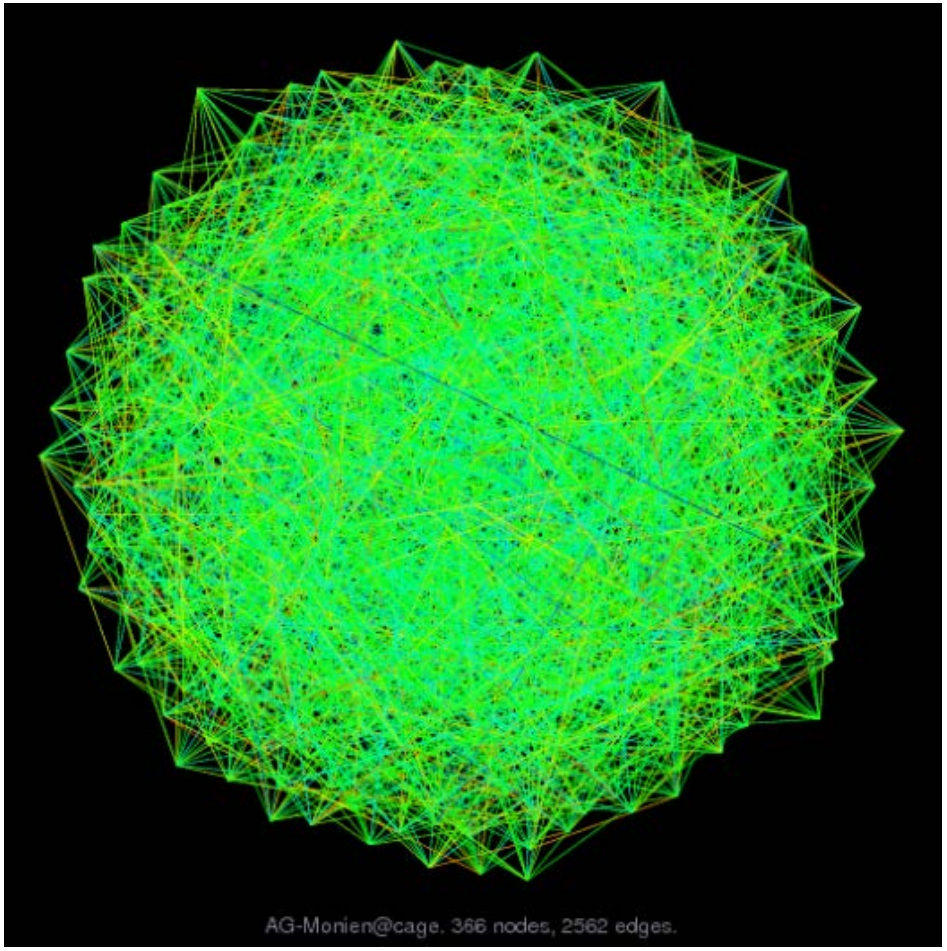
After this course, you can be a developer of visualization systems/techniques not just a user

Topics to Be Covered in this Course

- What will be covered?
  - Colors, perception
  - Scalar field visualization
  - Vector field visualization
  - Tensor field visualization
  - Information visualization (plots, graphs, high-dimensional, etc.)
- What mathematical knowledge will be needed?
  - Calculus, trigonometry, linear algebra, discrete math, topology, dynamical systems, numerical algebra, etc.
- What knowledge from the other sub-fields of computer science will be needed?
  - **Algorithms, data structures, C++ programming**, computer graphics, human-computer interaction, imaging processing, etc.
- Anything else?
  - **Art and design**, psychophysics, scientific computing, other domain related knowledge

Preview of Topics

Why visualization can easily go wrong?



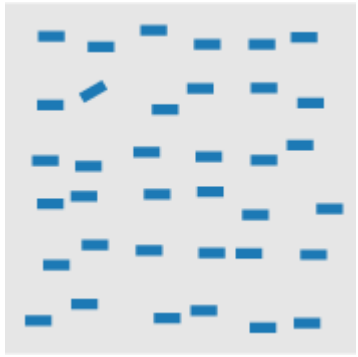
http://yifanhu.net/GALLERY/GRAPHS/

Rainbow distribution in color indicates sales rank in given country from #1 (red) to #10 or higher (dark purple)

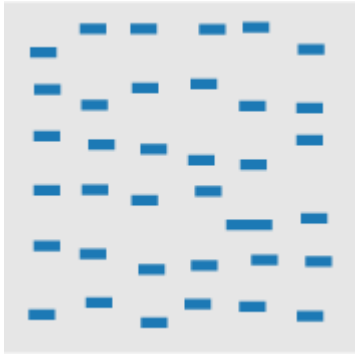
Country	A	B	C	D	E
AUS	1	2	3	6	7
BRA	1	3	4	5	6
CAN	2	3	6	12	8
CHI	1	2	8	4	7
FRA	3	2	4	8	10
GER	3	1	6	5	4
IND	4	1	8	10	5
ITA	2	4	10	9	8
MEX	1	5	4	6	3
RUS	4	3	7	9	12
SPA	2	3	4	5	11
TUR	7	2	3	4	8
UK	1	2	3	6	7
US	1	2	4	3	5

Images from the storytelling with data

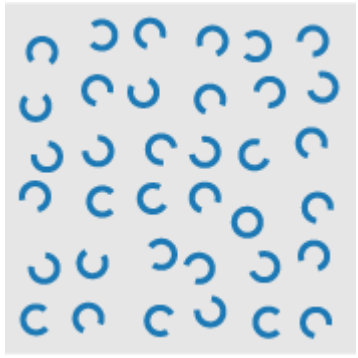
Perception



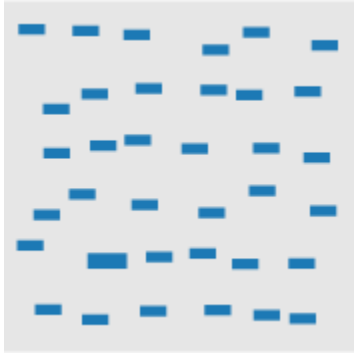
Blob orientation



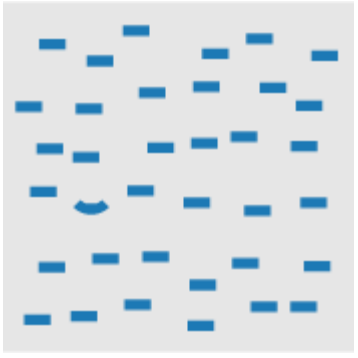
length, width



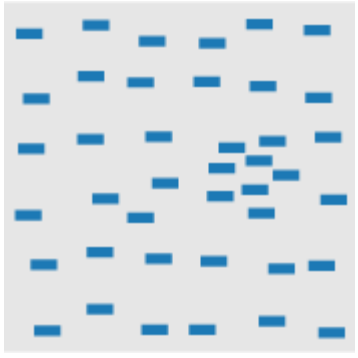
closure



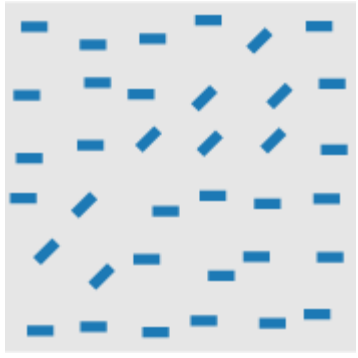
size



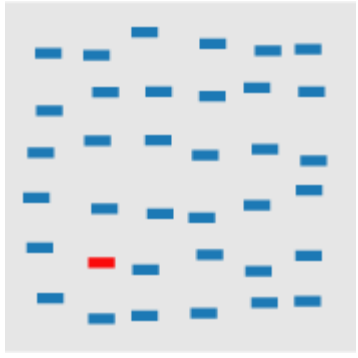
Curvature



density, contrast



number, estimation

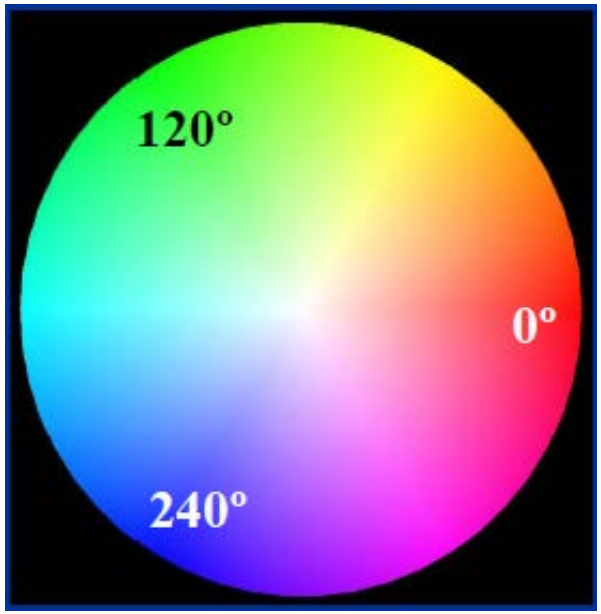


color(hue)

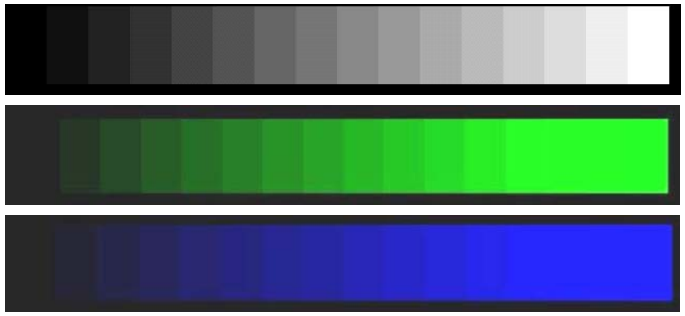
C. Healey and J. Enns, “Attention and Visual Memory in Visualization and Computer Graphics”, IEEE Transactions on Visualization and Computer Graphics, 2011

Colors

- Color theory and visual representation



HSV Color Wheel



How to use colors effectively?

Rainbow distribution in color indicates sales rank in given country from #1 (red) to #10 or higher (dark purple)

Country	A	B	C	D	E
AUS	1	2	3	6	7
BRA	1	3	4	5	6
CAN	2	3	6	12	8
CHI	1	2	8	4	7
FRA	3	2	4	8	10
GER	3	1	6	5	4
IND	4	1	8	10	5
ITA	2	4	10	9	8
MEX	1	5	4	6	3
RUS	4	3	7	9	12
SPA	2	3	4	5	11
TUR	7	2	3	4	8
UK	1	2	3	6	7
US	1	2	4	3	5

RANK 1 2 3 4 5+

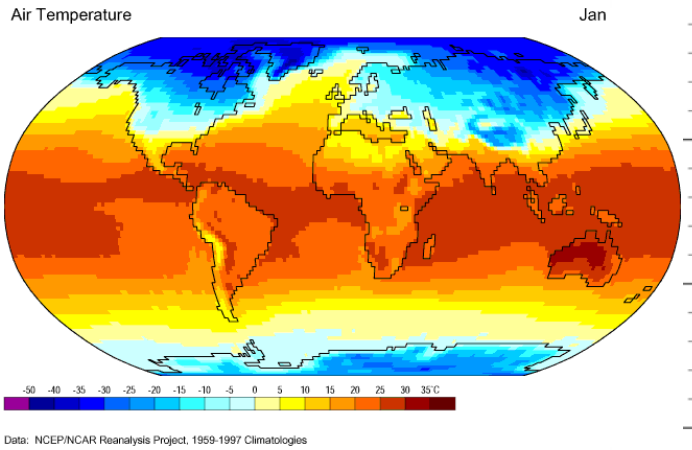
COUNTRY | DRUG

	A	B	C	D	E
Australia	1	2	3	6	7
Brazil	1	3	4	5	6
Canada	2	3	6	12	8
China	1	2	8	4	7
France	3	2	4	8	10
Germany	3	1	6	5	4
India	4	1	8	10	5
Italy	2	4	10	9	8
Mexico	1	5	4	6	3
Russia	4	3	7	9	12
Spain	2	3	4	5	11
Turkey	7	2	3	4	8
United Kingdom	1	2	3	6	7
United States	1	2	4	3	5

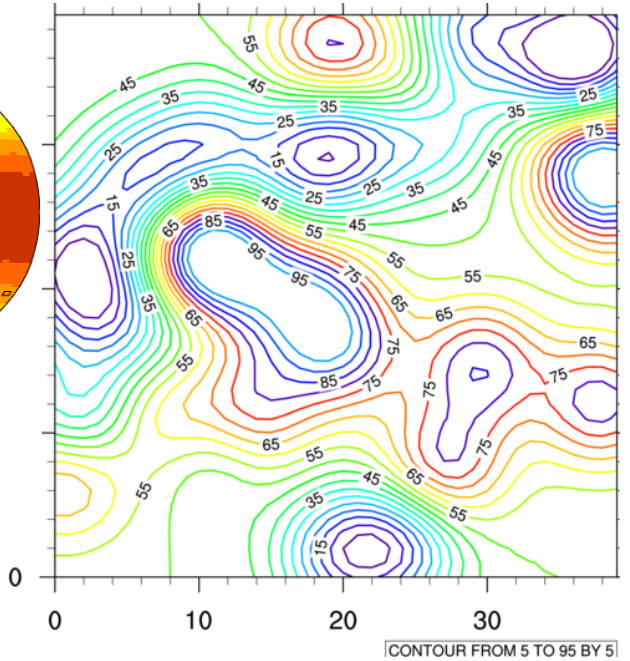
Images from the storytelling with data

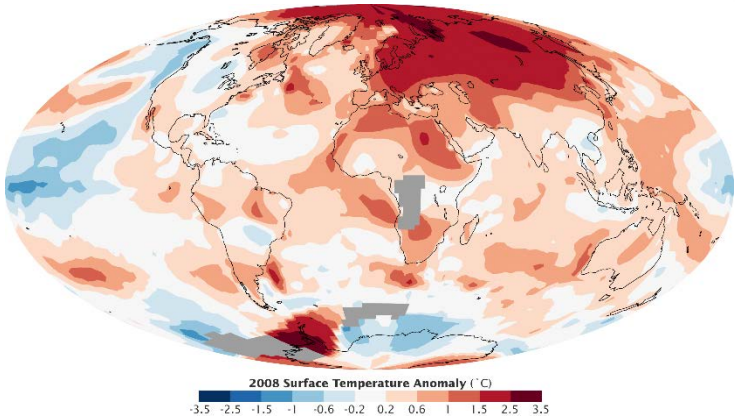
Scalar Field Visualization

- Applications
  - Medical
  - Physics
  - Engineering
  - Climate
  - Environment
  - ……
- 2D/2.5D

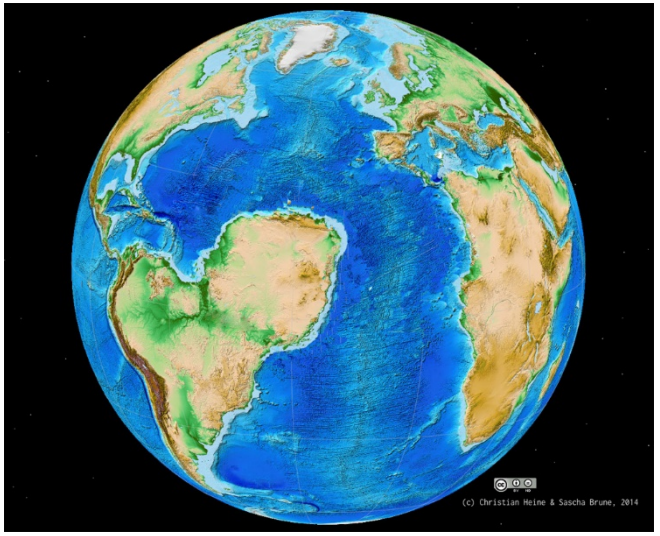


Global temperature average



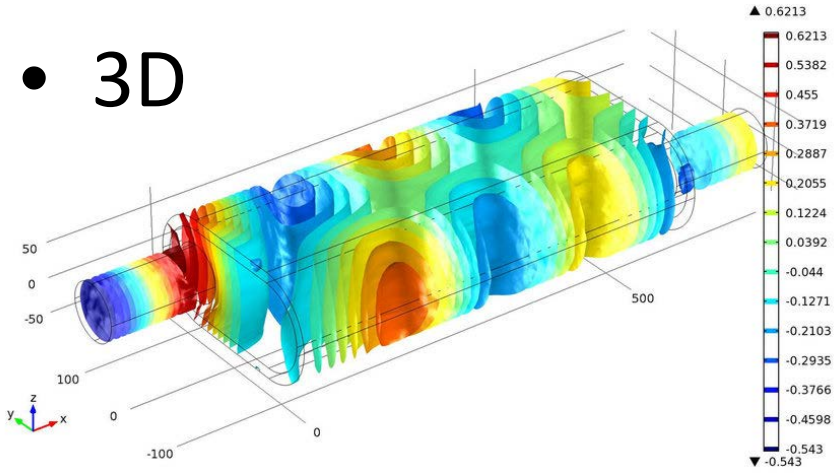


Global temperature 2008



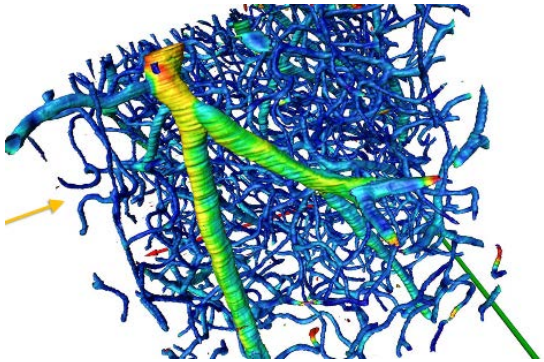
Scalar Field Visualization

- 3D

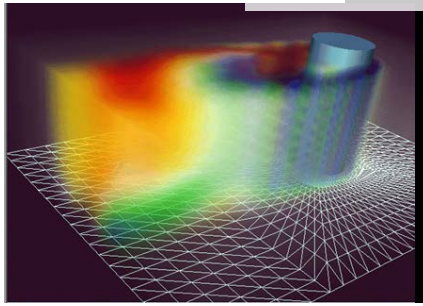


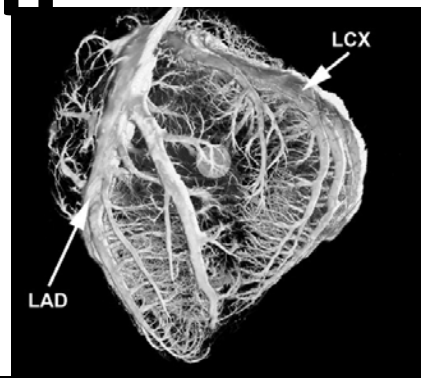
Isosurface-Total acoustic pressure field

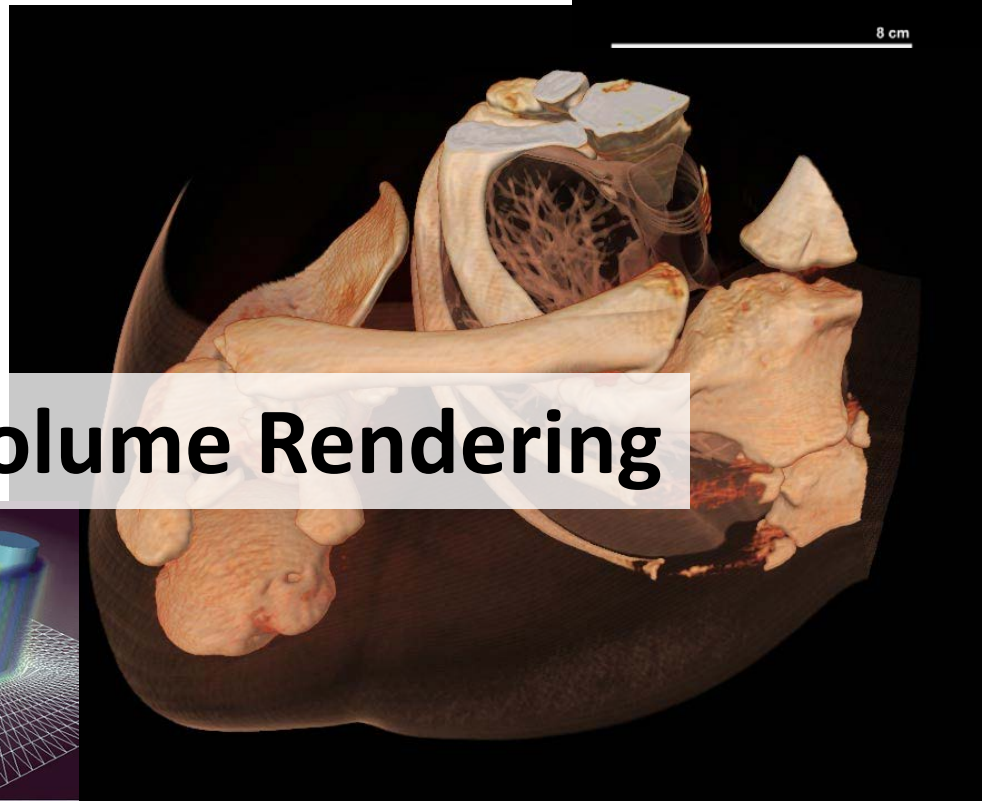
Iso-surfacing



Microvasculature



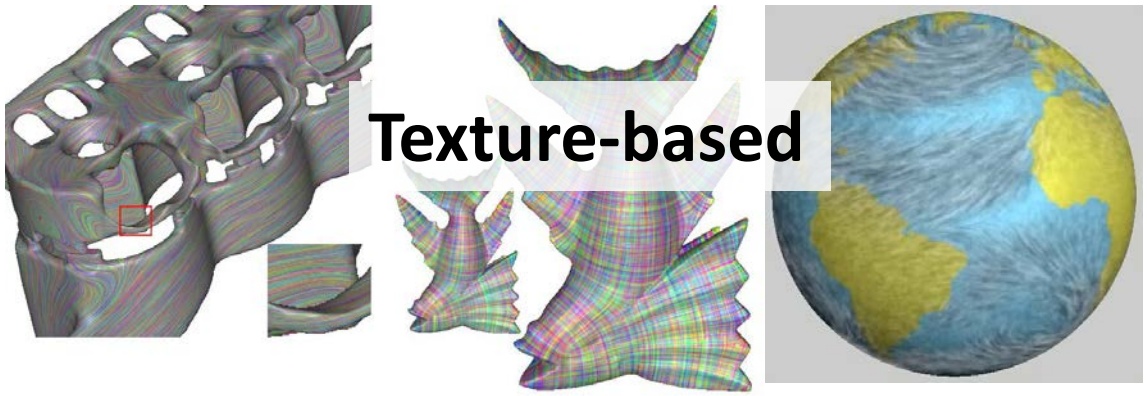


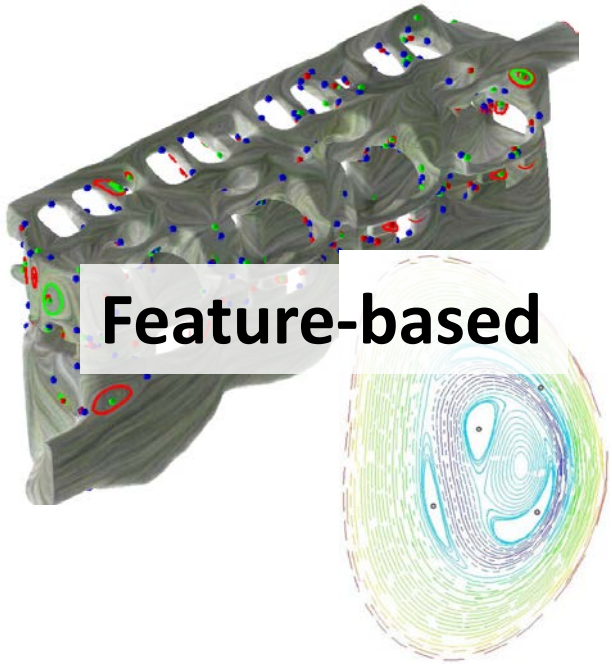


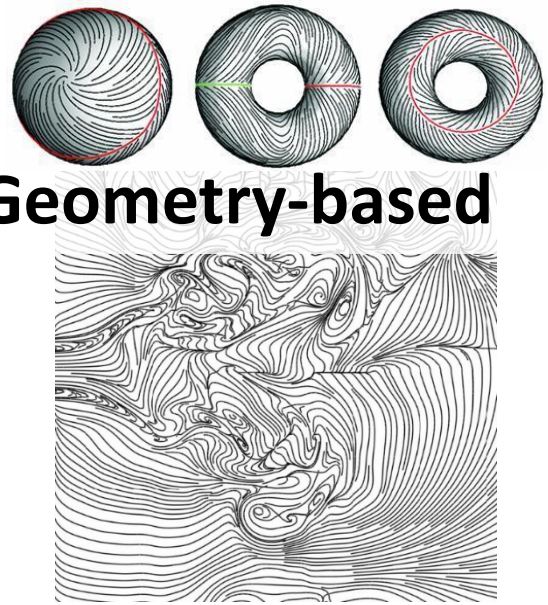
Volume Rendering

Vector Field Visualization

- Applications
  - Medical
  - Physics
  - Engineering
  - Climate
  - Environment
  - Oceanography
  - ……
- 2D

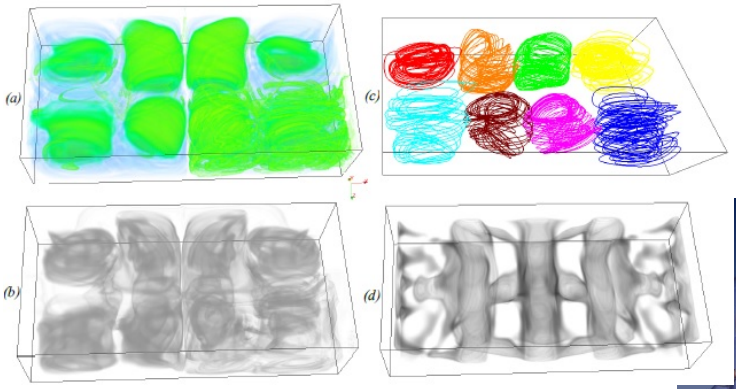


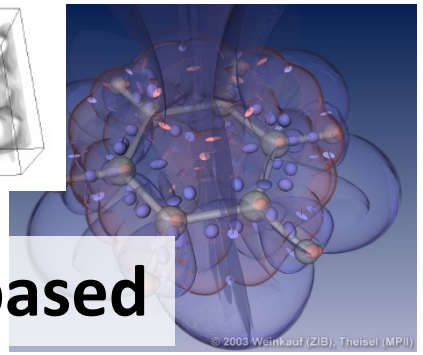




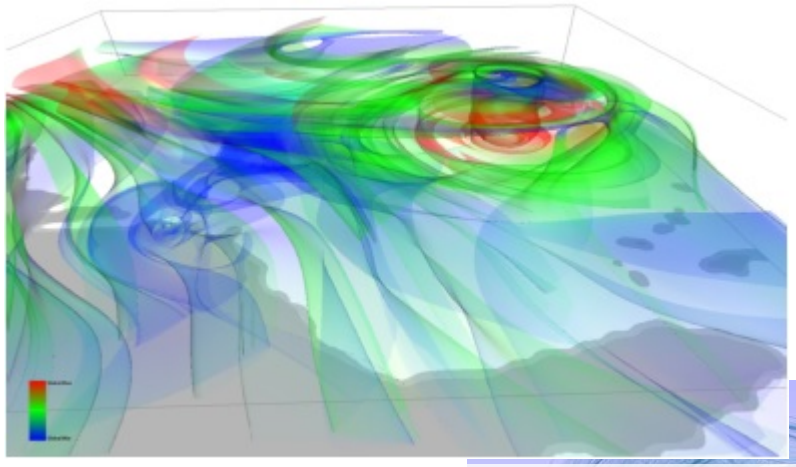
Vector Field Visualization

- 3D

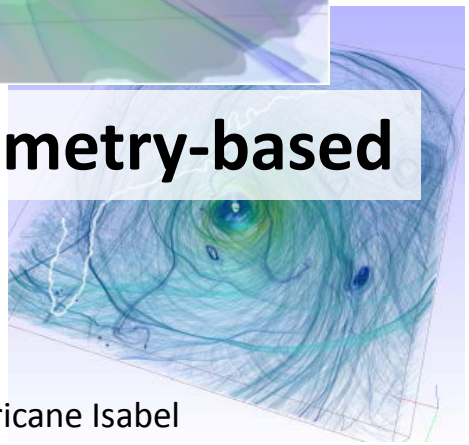




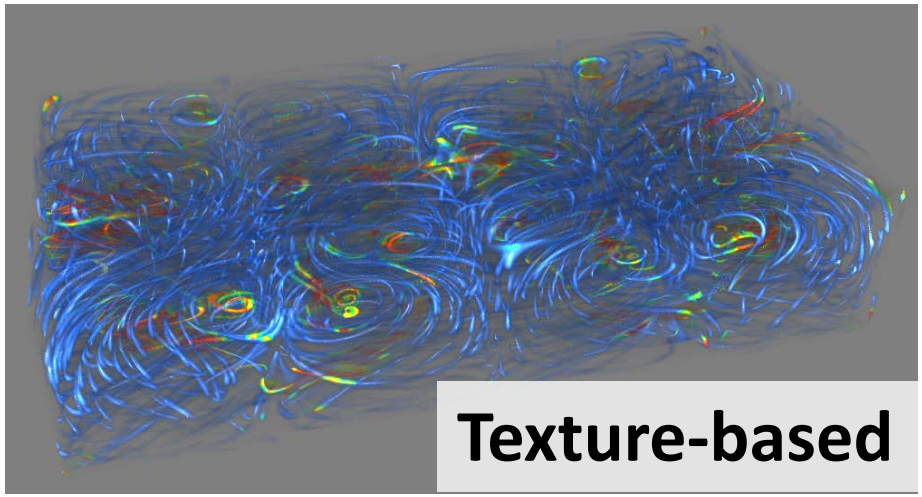
Feature-based



Geometry-based



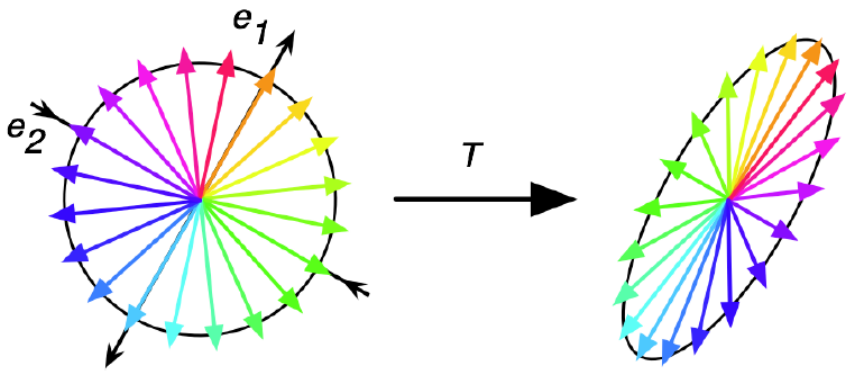
Hurricane Isabel



Texture-based

Tensor Field Visualization

- Applications
  - Physics
  - Engineering
  - Medical
  - ……

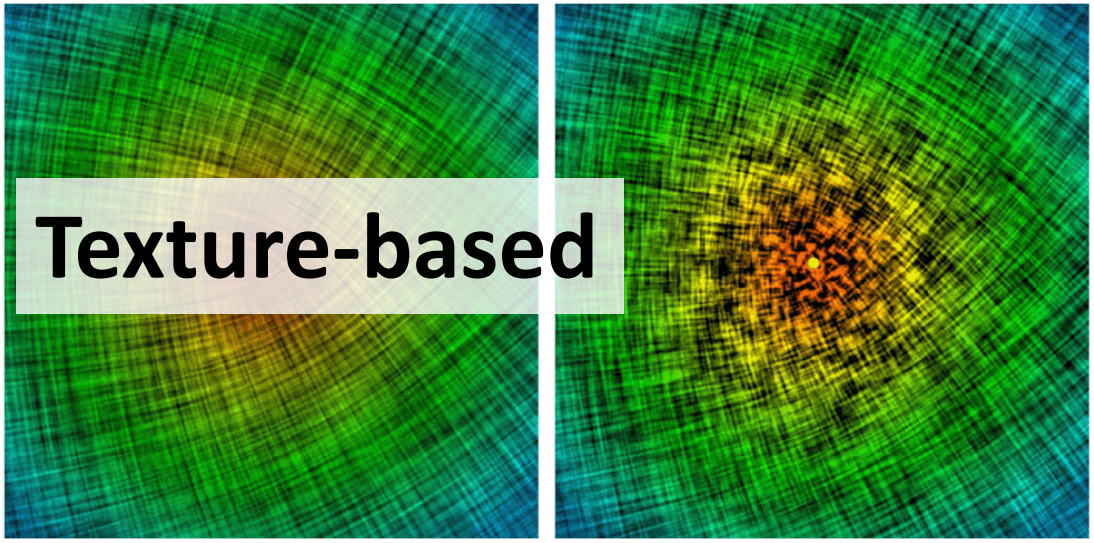


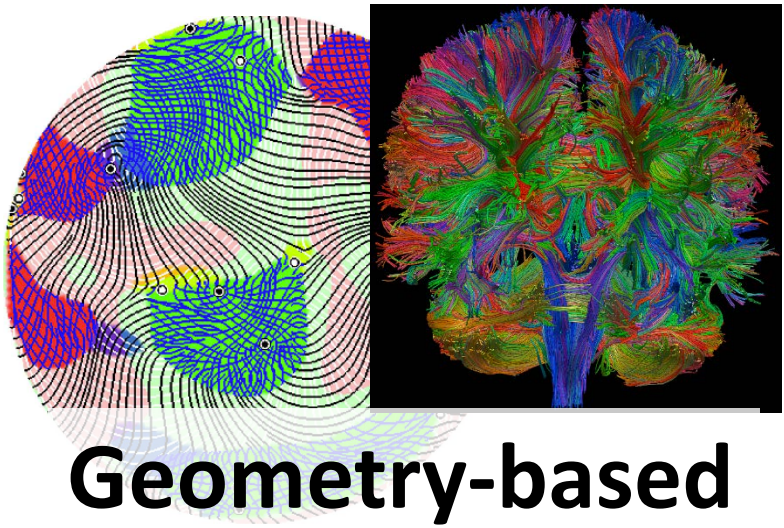
Second order tensor

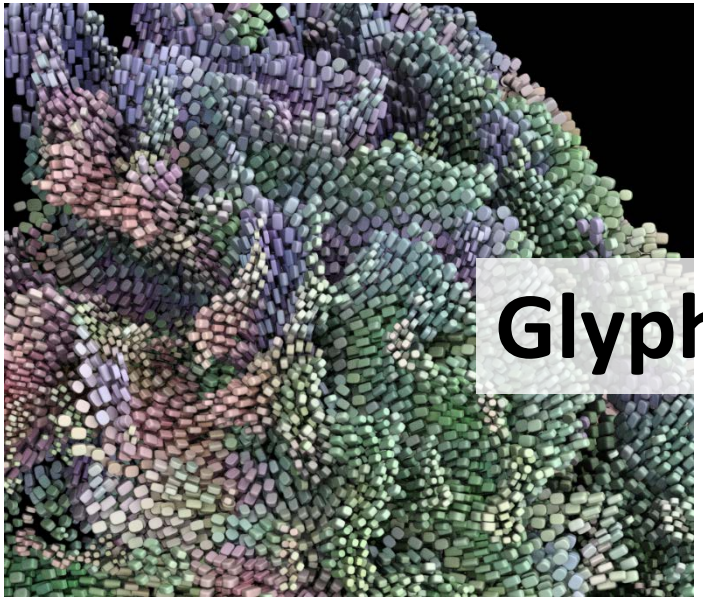
$$T = \begin{bmatrix} T_{00}(x,y,z) & & \\ & \ddots & \\ & & \end{bmatrix}$$

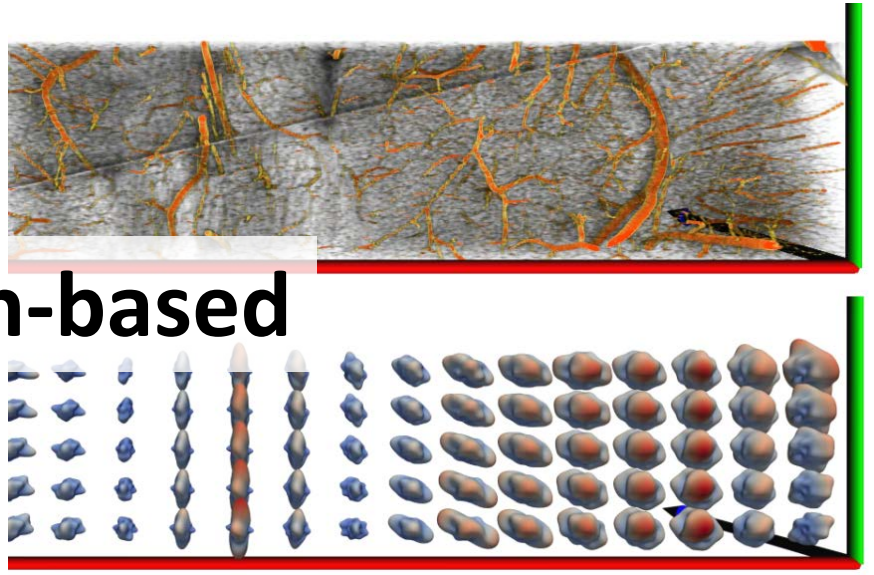
- A rather complex but powerful notation

Tensor field visualization

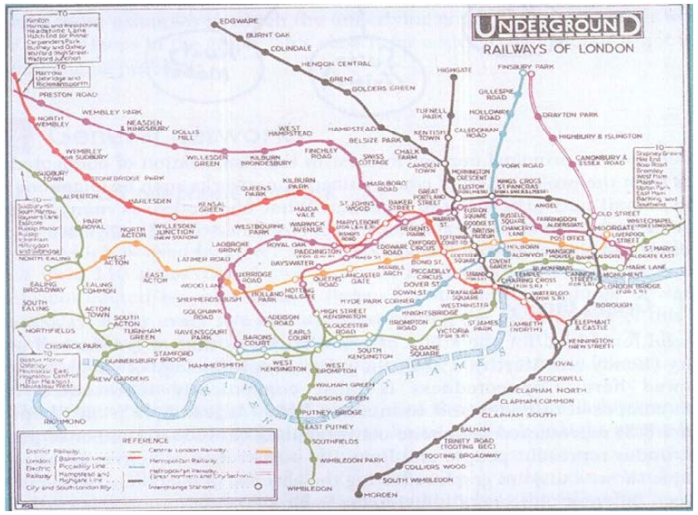






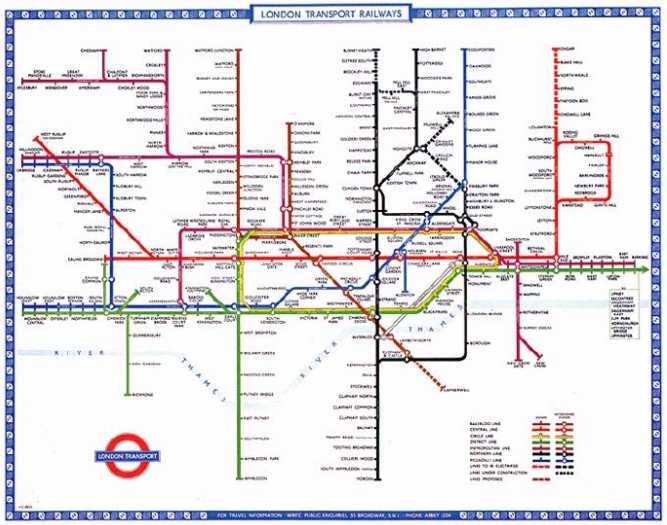


Graphs and Charts

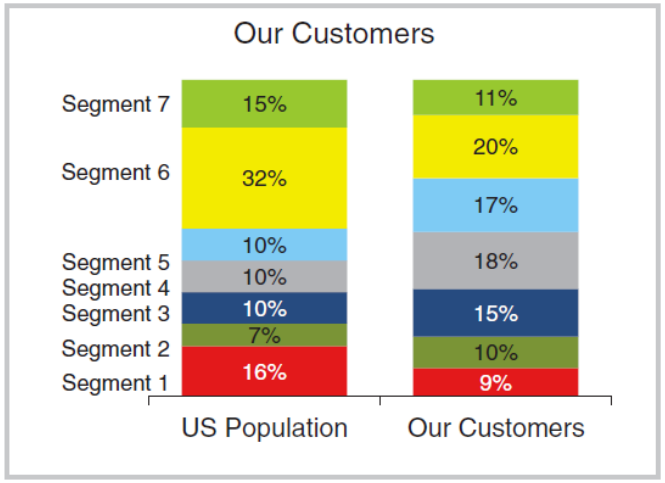


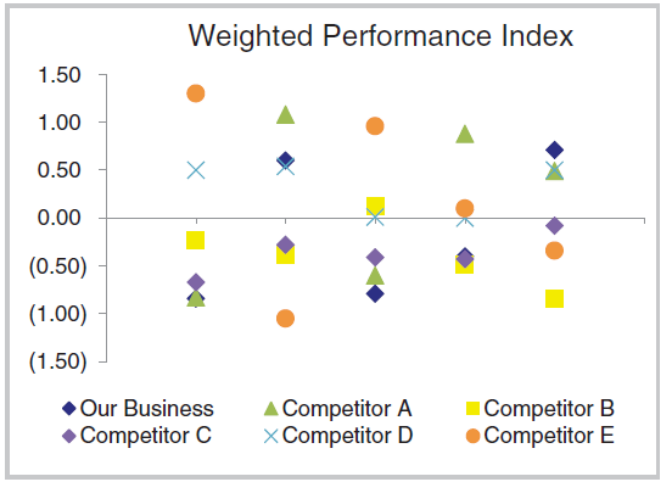
London Subway Map, 1927

Abstract



Harry Beck, 1933





Bad graphs vs. good graphs

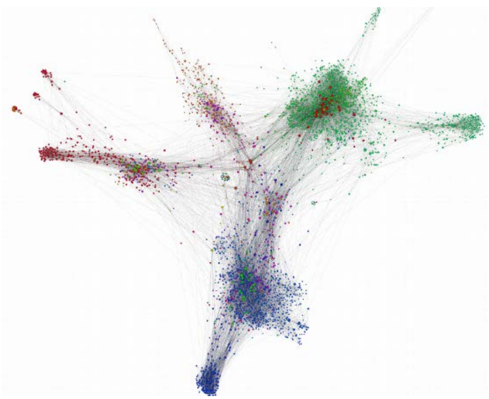
Images from the storytelling with data

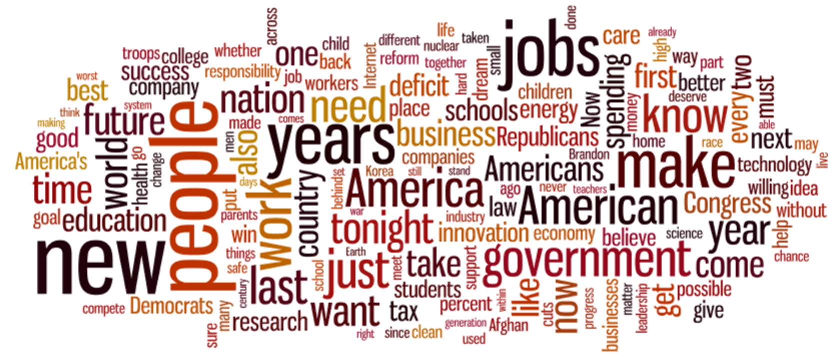
Graphs and Charts

FOUR QUESTIONS

1. What data is important to show?
2. What do I want to emphasize in the data?
3. What options do I have for displaying this data?
4. Which option is most effective in communicating the data?

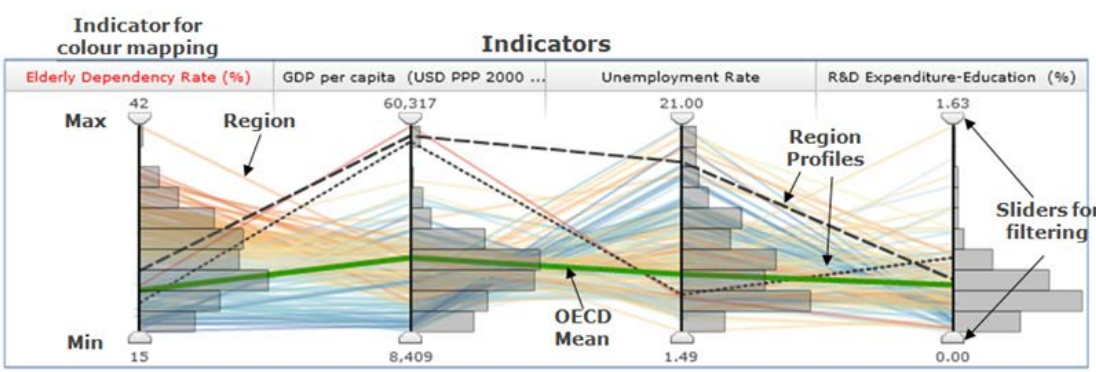
Information visualization





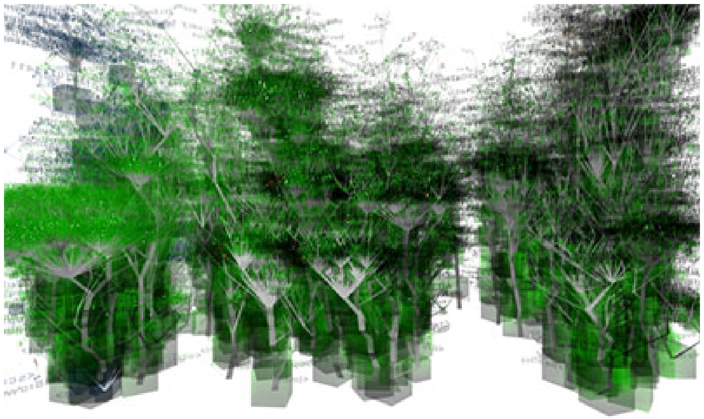
Text visualization http://www.poynter.org

Graph visualization http://gephi.org



High-dimensional data visualization

http://ncva.itn.liu.se/great-statistics-visualization/



Tree/hierarchy data visualization

http://infosthetics.com