

CSE 332

# INTRODUCTION TO VISUALIZATION

## INTRODUCTION

**KLAUS MUELLER**

COMPUTER SCIENCE DEPARTMENT  
STONY BROOK UNIVERSITY

# WHAT'S VISUALIZATION?

First hit on Google Image:



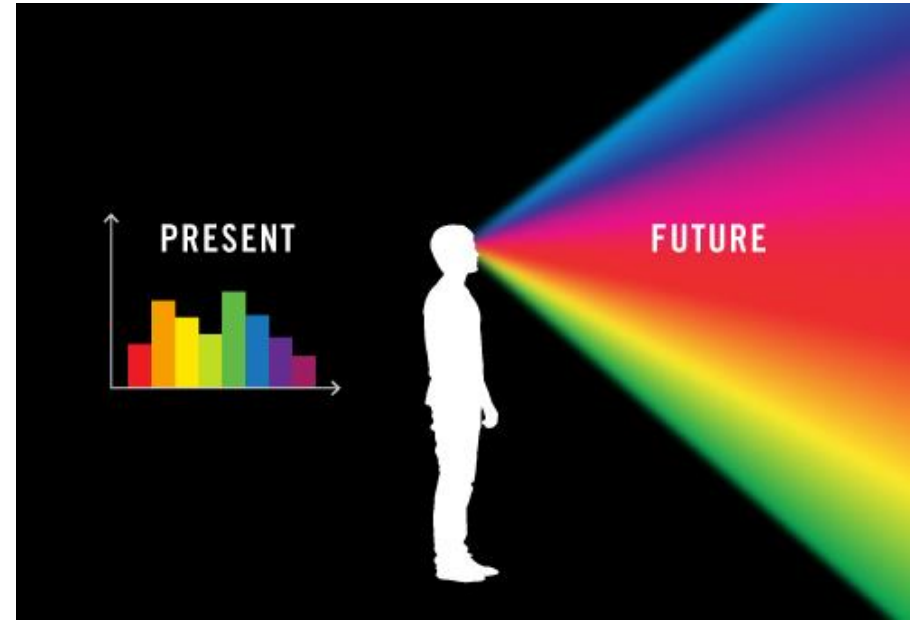
Creative visualization is a mental technique that uses the imagination to make dreams and goals come true.

Used in the right way, creative visualization can improve your life and attract to you success and prosperity.

It can alter your circumstances, cause events to happen, and attract money, possessions, work, people, and love into your life.

# NO, IT'S THE OTHER VISUALIZATION

Second hit on Google Image:



It shares the “imagination” part

And these days, it can also bring you “success and prosperity”

And it may “attract work, people, and love into your life”

WHY VISUALIZATION?

# RICH HISTORY

Let's go back some 150 years to 1854, London, England



# NEWSFLASH, 1854

The most terrible outbreak of cholera which ever occurred in this kingdom, is probably that which is taking place in Broad Street, Golden Square, and adjoining streets.

Within two hundred and fifty yards of the spot where Cambridge Street joins Broad Street, there are upwards of five hundred fatal attacks of cholera in ten days.

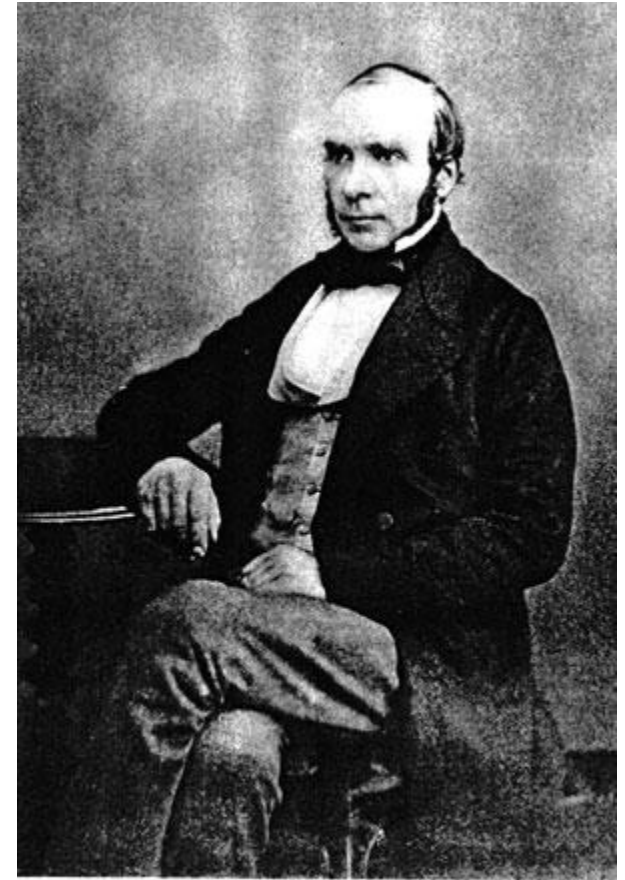
The mortality in this limited area probably equals any that was ever caused in this country, even by the plague; and it is much more sudden, as the greater number of cases terminated in a few hours.

WHAT CAN WE DO?

WHAT IS THE CAUSE?

HOW CAN WE ELIMINATE IT?

# TIME FOR “IMAGINATION”



*John Snow*



# PROVED THE HYPOTHESIS

## Cholera spreads through water

- and not via some other fantastic causes
- one said it rose out of the burying grounds of plague victims from two centuries earlier
- the bacteria was discovered later, in 1886

## A real-life experiment

- established the mode of cholera transmission
- and consequently the method of prevention: keep drinking water, food, and hands clear of infected sewage

## Visualization provided

- inspiration
- convincing arguments to justify actions
- led to Dr. John Snow's historic immortality
- a bar near the old Broad Street pump bears his name (safe drinking)

WHAT IS NEEDED FOR VISUALIZATION?

# WHAT IS NEEDED FOR VISUALIZATION – SOME APPROPRIATE ANSWERS

Data (wide variety)

Algorithms

- data mining
- data analytics
- machine learning

Computer

- run those algorithms
- data storage

Humans

- with a purpose/need to understand their data
- endowed with cognitive faculties, creative thought, intuition
- domain expertise

Understanding of humans

- perception, cognition, HCI issues
- we can gain it through experimentation with humans

= Visual Analytics

# DR. JOHN SNOW: A VISUAL ANALYTICS PIONEER

## Dr. John Snow's London Cholera Map of 1854

- data collection
- data assimilation
- statistical testing
- visualization
- computational analysis (brain)
- domain knowledge

Very early example of  
visual analytics

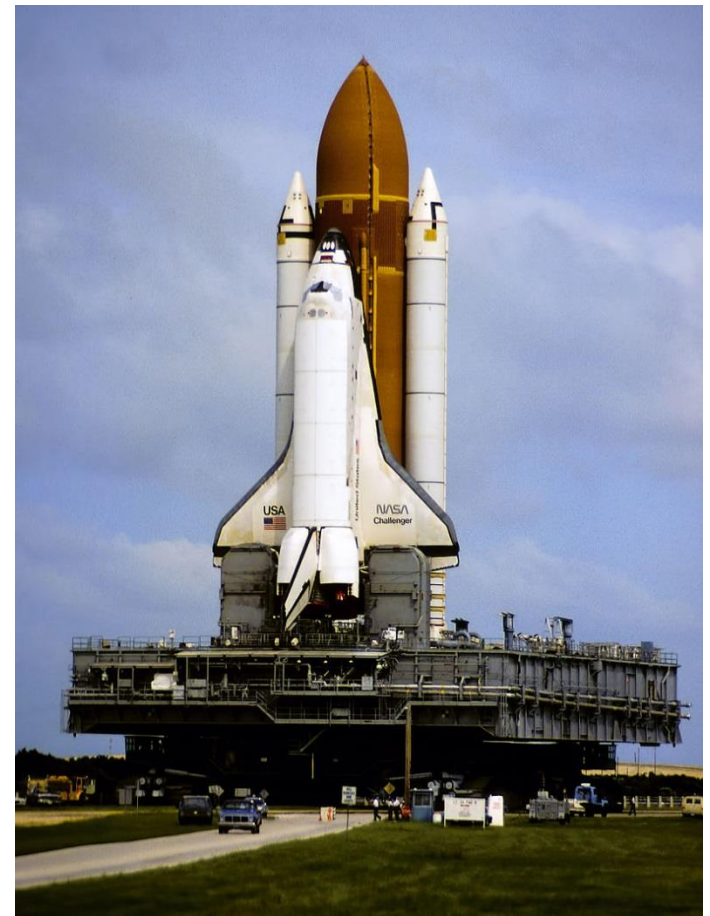


# MORE RECENT HISTORY

Let's go back some 30 years to 1986, JFK Space Center, FL



The crew of Space Shuttle mission STS-51-L 11/15/85. Back row, left to right: Ellison S. Onizuka, Sharon Christa McAuliffe, Greg Jarvis, Judy Resnik. Front row, left to right: Michael J. Smith, Dick Scobee, Ron McNair.



73 SECONDS AFTER LIFT-OFF



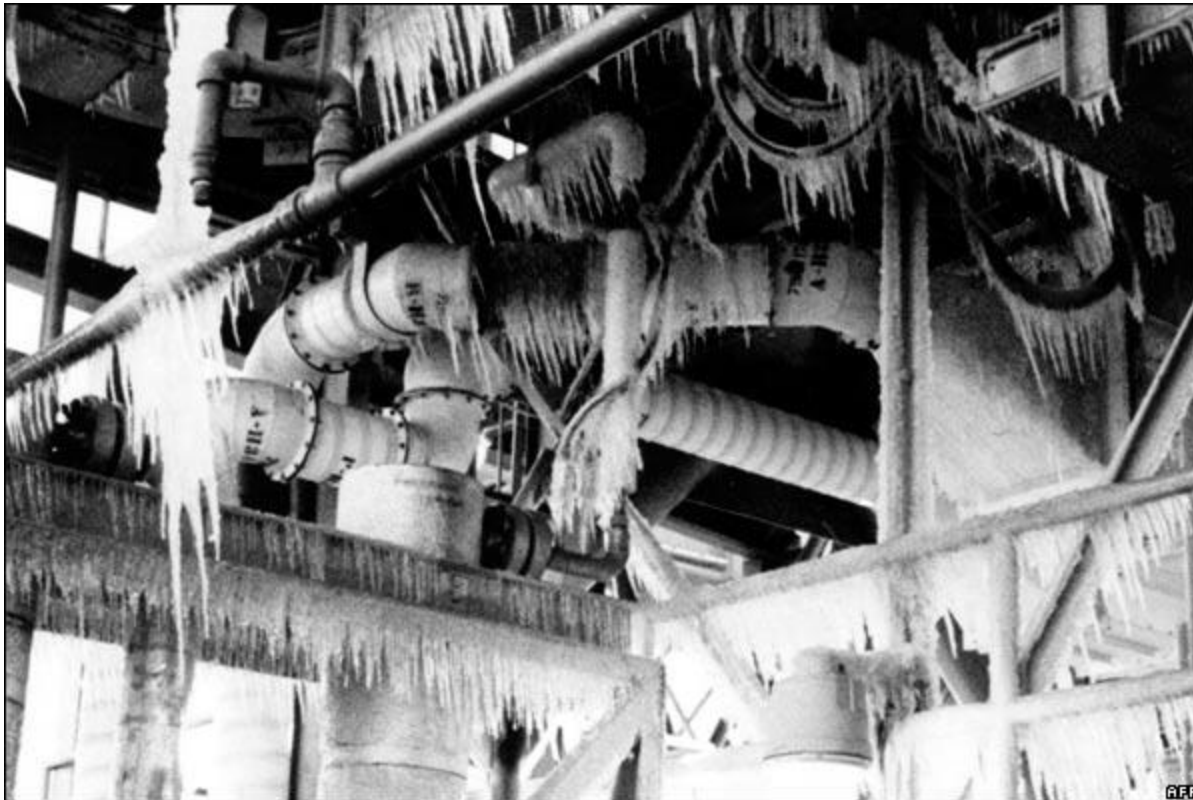
WHAT HAPPENED?

WHAT WAS THE CAUSE?



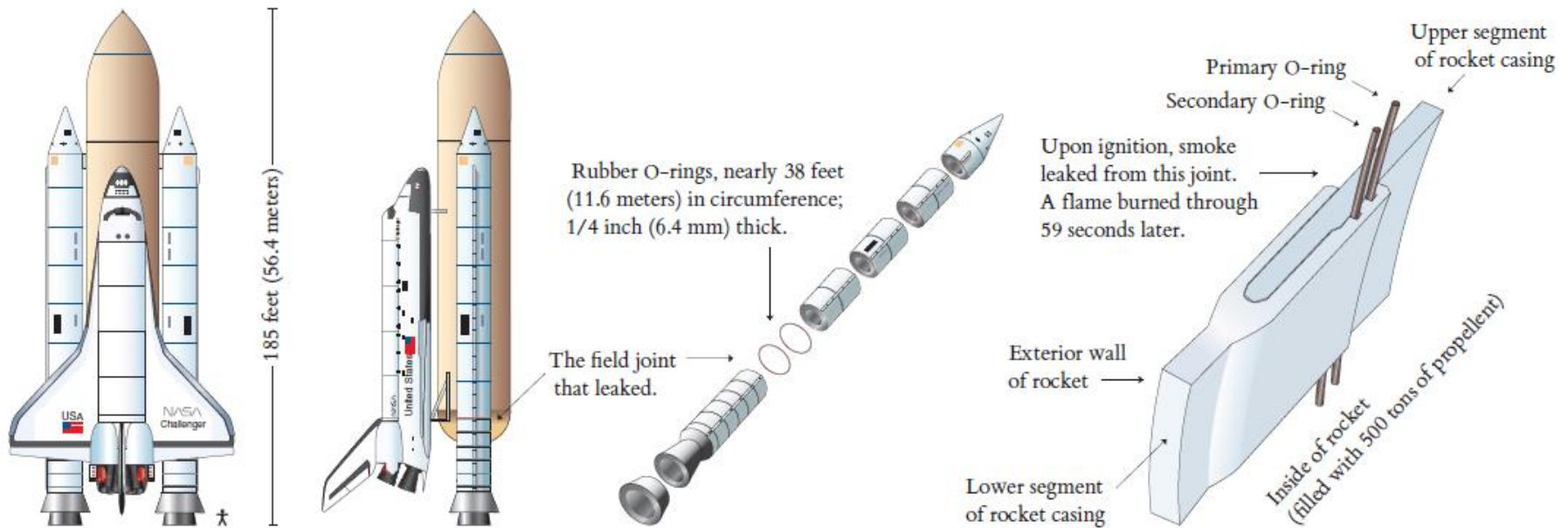
# THE DAY OF THE LAUNCH

36 degrees F on Launch Pad 39





# SPACE SHUTTLE 101



# FAST FORWARD

## 58 SECONDS AFTER IGNITION



WHAT HAPPENED?

WHAT WAS THE CAUSE?

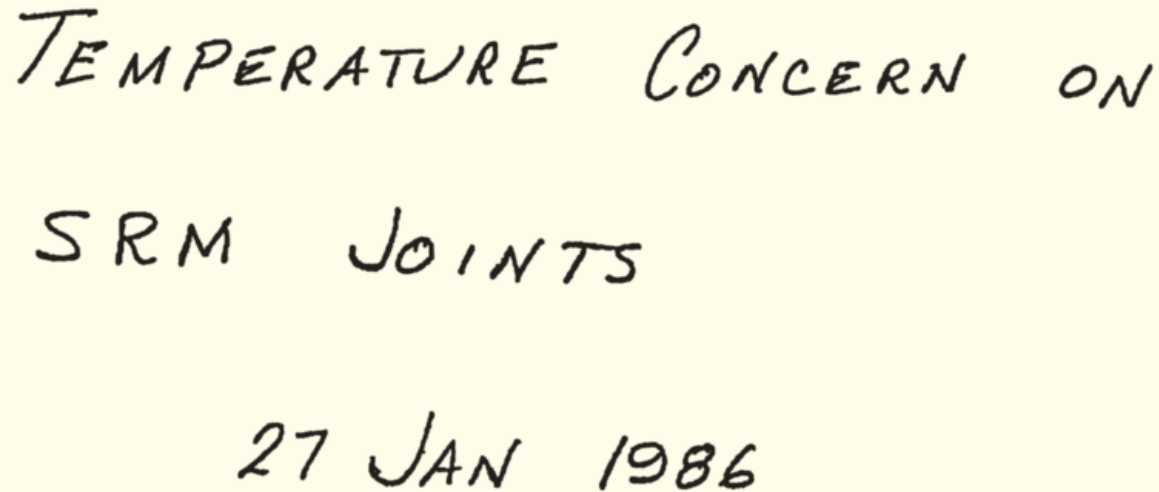
COULD IT HAVE BEEN PREVENTED?

# ENGINEERS AT THIOKOL HAD A HUNCH

Two days before launch they presented their concerns

- created 13 charts to make their case

Slide #1:



TEMPERATURE CONCERN ON  
SRM JOINTS  
27 JAN 1986

- SRM – Solid Rocket Motor

# SLIDE #2

## Teaches about past damages to O-ring

1169  
Oct 30, 1985  
y<sup>r</sup>

61A LH Center Field\*\*  
61A LH CENTER FIELD\*\*  
51C LH Forward Field\*\*  
51C RH Center Field (prim)\*\*\*  
51C RH Center Field (sec)\*\*\*

41D RH Forward Field  
41C LH Aft Field\*  
41B LH Forward Field

July STS-2 RH Aft Field

HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

SRM No.	Cross Sectional View			Top View		Clocking Location (deg)
	Erosion Depth (in.)	Perimeter Affected (deg)	Nominal Dia. (in.)	Length Of Max Erosion (in.)	Total Heat Affected Length (in.)	
22A	None	None	0.280	None	None	36° -- 66°
22A	NONE	NONE	0.280	NONE	NONE	338° - 18°
15A	0.010	154.0	0.280	4.25	5.25	163
15B	0.038	130.0	0.280	12.50	58.75	354
15B	None	45.0	0.280	None	29.50	354
13B	0.028	110.0	0.280	3.00	None	275
11A	None	None	0.280	None	None	--
10A	0.040	217.0	0.280	3.00	14.50	351
2B	0.053	116.0	0.280	--	--	90

\*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.

\*\*Soot behind primary O-ring.

\*\*\*Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

# SLIDES #2 AND 3

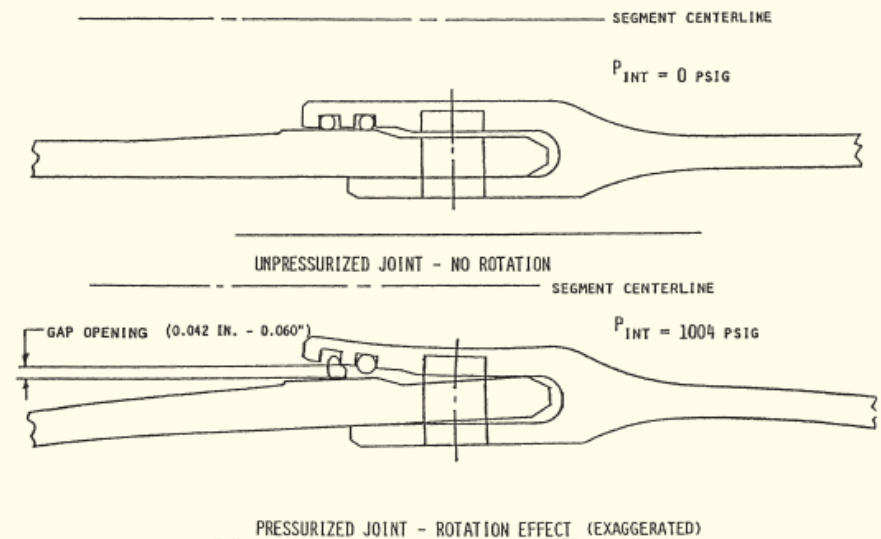
## Teaches about O-ring damage mechanics and erosion

### PRIMARY CONCERNS -

#### FIELD JOINT - HIGHEST CONCERN

- o EROSION PENETRATION OF PRIMARY SEAL REQUIRES RELIABLE SECONDARY SEAL FOR PRESSURE INTEGRITY
  - o IGNITION TRANSIENT - (0-600 MS)
    - o (0-170 MS) HIGH PROBABILITY OF RELIABLE SECONDARY SEAL
    - o (170-330 MS) REDUCED PROBABILITY OF RELIABLE SECONDARY SEAL
    - o (330-600 MS) HIGH PROBABILITY OF NO SECONDARY SEAL CAPABILITY
- o STEADY STATE - (600 MS - 2 MINUTES)
  - o IF EROSION PENETRATES PRIMARY O-RING SEAL - HIGH PROBABILITY OF NO SECONDARY SEAL CAPABILITY
    - o BENCH TESTING SHOWED O-RING NOT CAPABLE OF MAINTAINING CONTACT WITH METAL PARTS GAP OPENING RATE TO MEOP
    - o BENCH TESTING SHOWED CAPABILITY TO MAINTAIN O-RING CONTACT DURING INITIAL PHASE (0-170 MS) OF TRANSIENT

### PRIMARY CONCERNS - CONT



# SLIDES #4 AND 5

Lists temperature and blow-by history for two SRMs

## BLOW BY HISTORY

SRM-15 WORST BLOW-BY

- 2 CASE JOINTS (80°), (110°) ARC
- MUCH WORSE VISUALLY THAN SRM-22

SRM 22 BLOW-BY

- 2 CASE JOINTS (30-40°)

SRM-13A, 15, 16A, 18, 23A 24A

- NOZZLE BLOW-BY

## HISTORY OF O-RING TEMPERATURES (DEGREES - F)

<u>MOTOR</u>	<u>MBT</u>	<u>AMB</u>	<u>O-RING</u>	<u>WIND</u>
DM-4	68	36	47	10 MPH
DM-2	76	45	52	10 MPH
QM-3	72.5	40	48	10 MPH
QM-4	76	48	51	10 MPH
SRM-15	52	64	53	10 MPH
SRM-22	77	78	75	10 MPH
SRM-25	55	26	29 27	10 MPH 25 MPH

# ASSUME YOU'RE A NASA MANAGER

Given the information provided in the company slides

- would you vote for a launch?
- ignore you know about the consequences



Be keenly aware of the immense PR pressures

- President Reagan's upcoming State of the Union speech
- the first civilian in space
- NASA's funding problems

Launch:

- **No:** OK with a PR disaster & possible budget cuts down the road
- **Yes:** the rocket company is too cautious & concerns are unproven



# WHY THE RECOMMENDATION FAILED

Presentation only has exactly two shuttle flights

- one with two blow-by's and high temperature
- one with two blow-by's and low temperature
- ignores all other 22 shuttle flights (SRM)

Statistically weak

Recommendation

- "O-ring temp must be  $> 53^{\circ}\text{F}$  at launch"
- is only based on a sample size of 1
- context of other flights is missing
- no statistical leverage

<u>MOTOR</u>	<u>O-RING</u>
DM-4	47
DM-2	52
QM-3	48
QM-4	51
SRM-15	53
SRM-22	75
SRM-25	29 27

Test rockets ignited on fixed horizontal platforms in Utah.

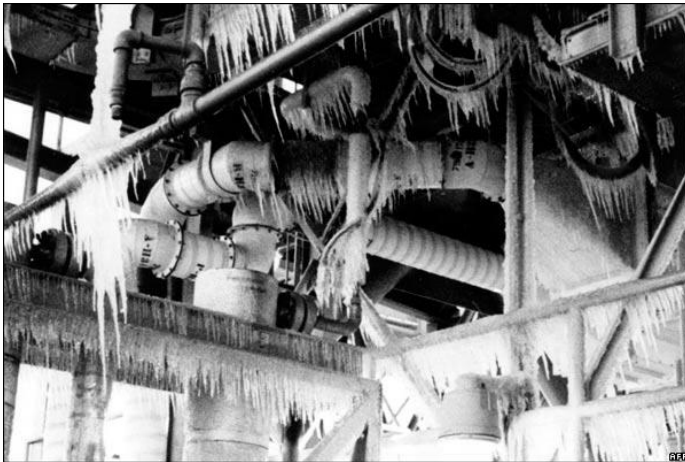
The only 2 shuttle launches (of 24) for which temperatures were shown in the 13 Challenger charts.

Forecasted O-ring temperatures for the Challenger.

# DEFICIENCIES

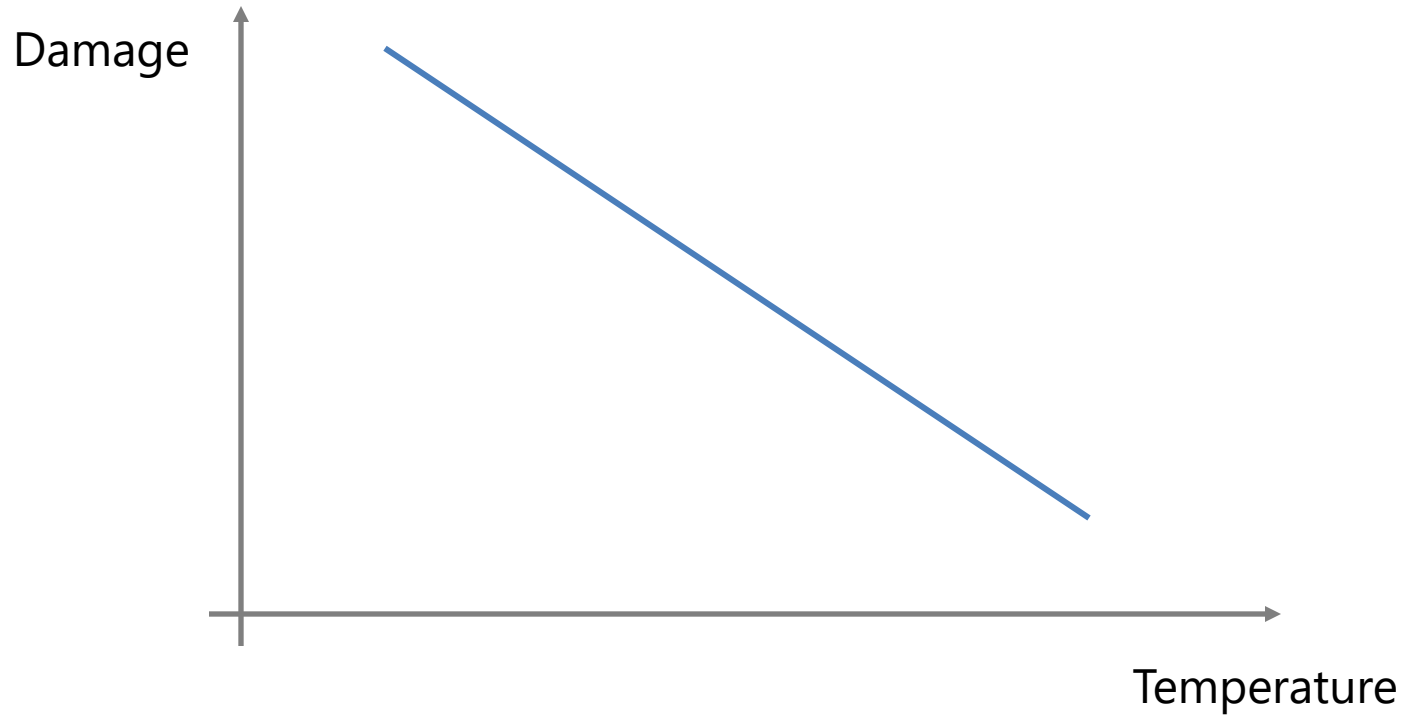
Lots of numbers and facts

But no causal evidence that could predict



What is needed?

# WHAT IS NEEDED?



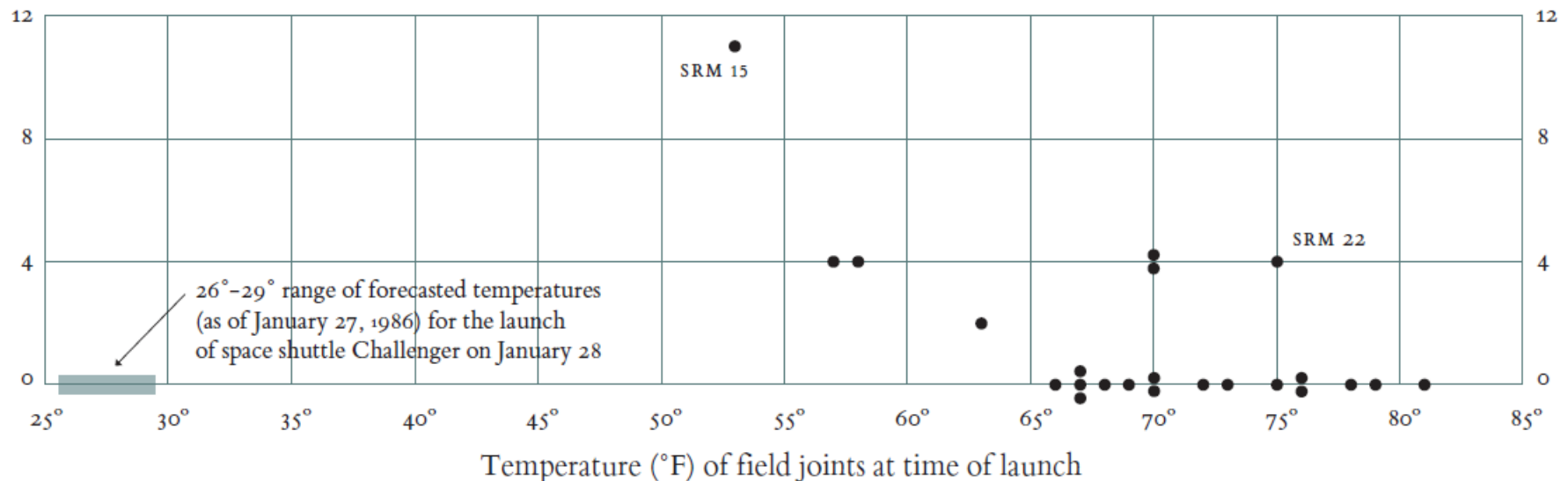
Need a measure for damage

# DAMAGE INDEX

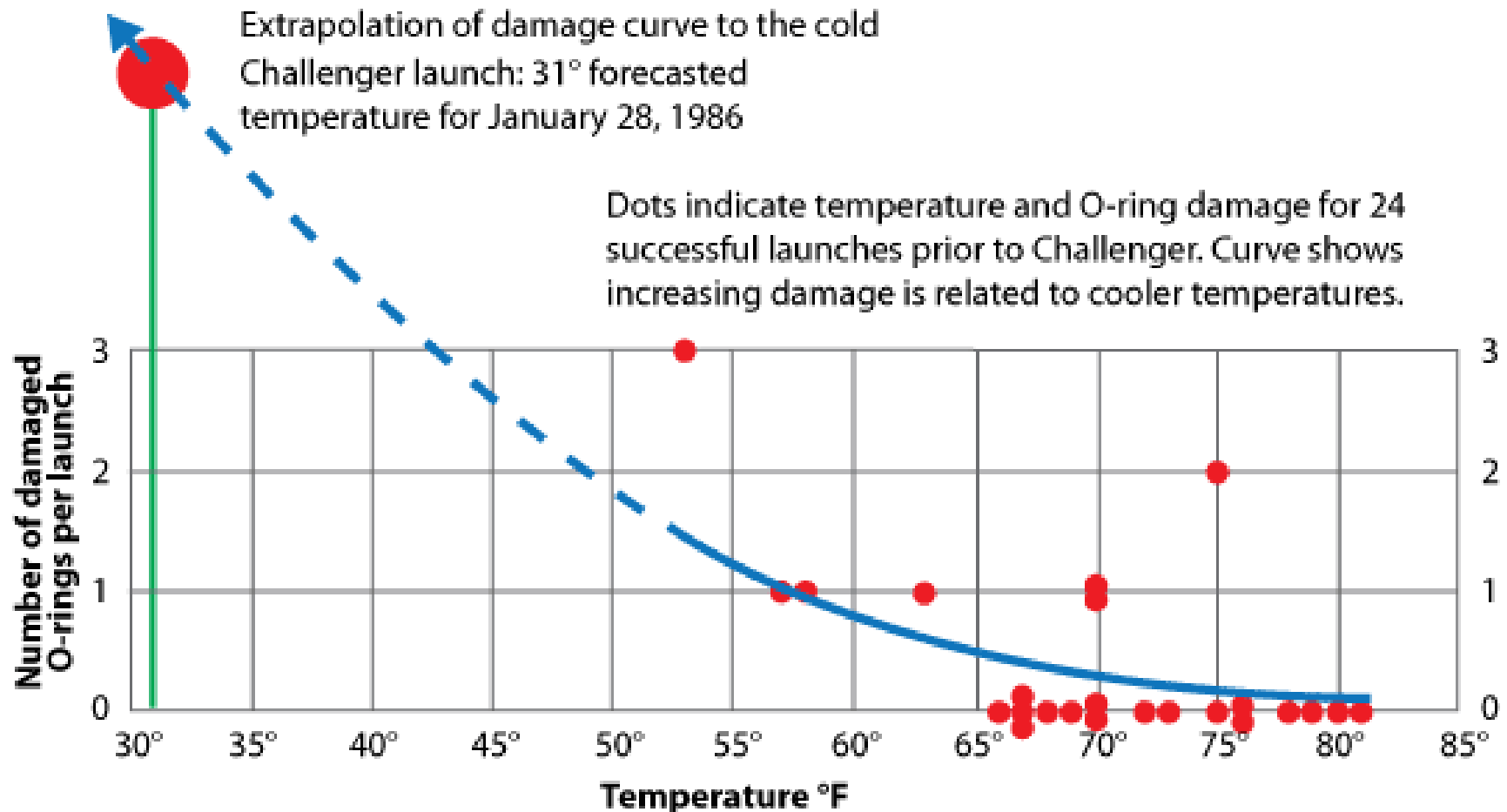
Flight	Date	Temperature °F	Erosion incidents	Blow-by incidents	Damage index	Comments
51-C	01.24.85	53°	3	2	11	Most erosion any flight; blow-by; back-up rings heated.
41-B	02.03.84	57°	1		4	Deep, extensive erosion.
61-C	01.12.86	58°	1		4	O-ring erosion on launch two weeks before Challenger.
41-C	04.06.84	63°	1		2	O-rings showed signs of heating, but no damage.
1	04.12.81	66°			0	Coollest (66°) launch without O-ring problems.
6	04.04.83	67°			0	
51-A	11.08.84	67°			0	
51-D	04.12.85	67°			0	
5	11.11.82	68°			0	
3	03.22.82	69°			0	
2	11.12.81	70°	1		4	Extent of erosion not fully known.
9	11.28.83	70°			0	
41-D	08.30.84	70°	1		4	
51-G	06.17.85	70°			0	
7	06.18.83	72°			0	
8	08.30.83	73°			0	
51-B	04.29.85	75°			0	
61-A	10.30.85	75°		2	4	No erosion. Soot found behind two primary O-rings.
51-I	08.27.85	76°			0	
61-B	11.26.85	76°			0	
41-G	10.05.84	78°			0	
51-J	10.03.85	79°			0	
	06.27.82	80°			?	O-ring condition unknown; rocket casing lost at sea.
51-F	07.29.85	81°			0	

# VISUALIZE IT – JUST THE FACTS

O-ring damage  
index, each launch

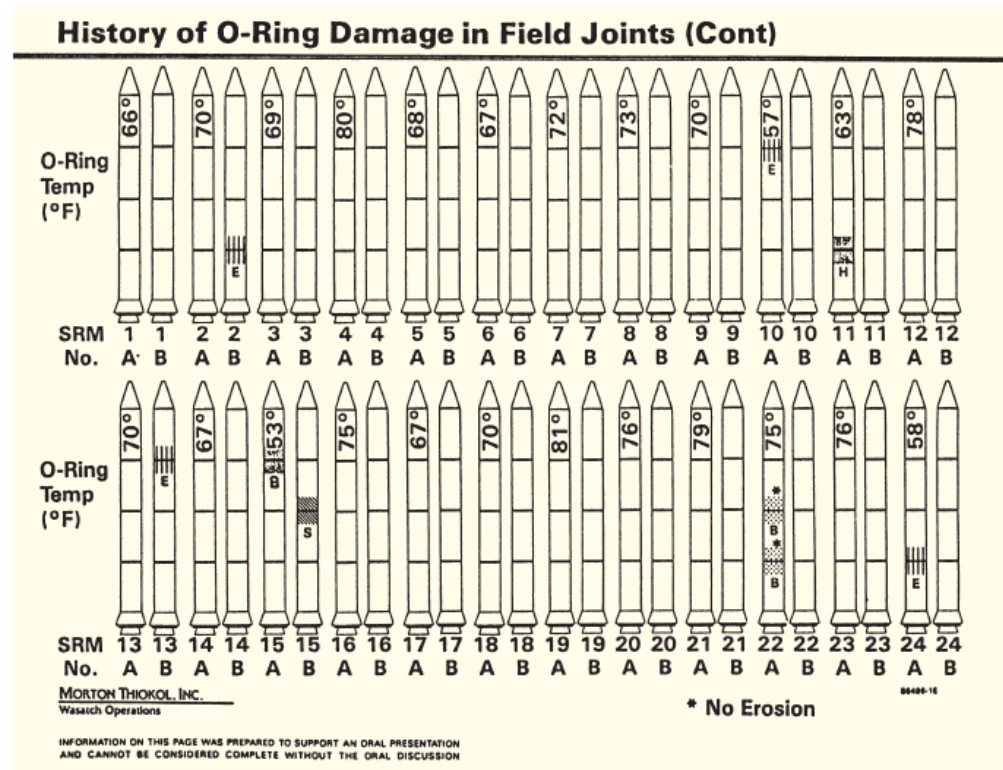


# VISUALIZE IT – TELL THE STORY



# SHOWN AT CONGRESSIONAL HEARINGS

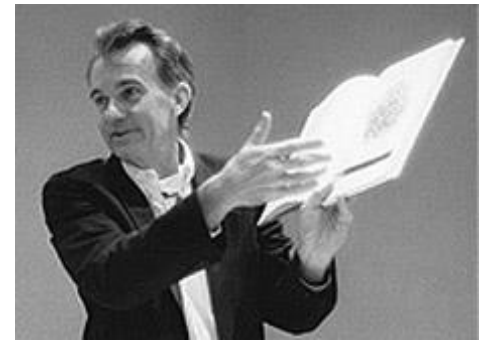
Used these charts



All information is there

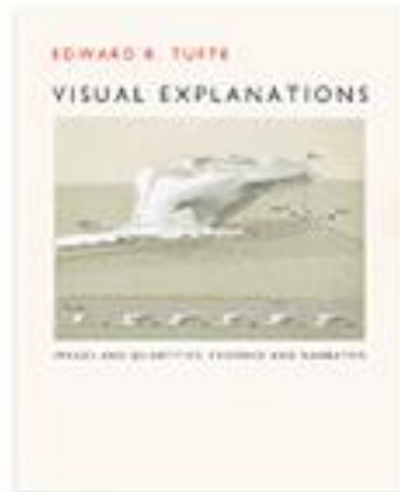
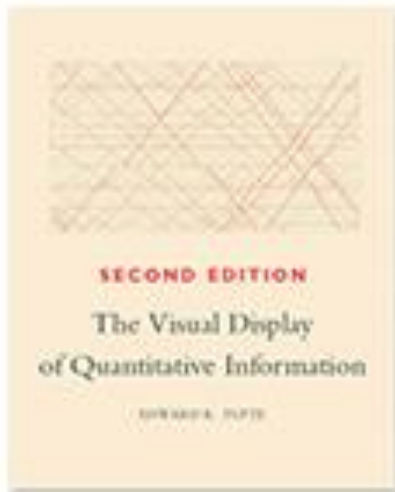
- but very hard to identify and assimilate
- why?

# SOURCE: EDWARD TUFTE



## Four seminal books

- standard literature for every visualization enthusiast
- written 1983, 1990, 1997, 2006



- taught information design at Princeton University
- now a professor at Yale University



# COURSE TOPICS



# SPATIAL DATA

shock wave

virtual frog

spiral flow

nerve cell

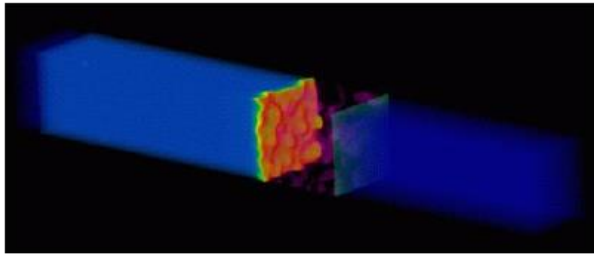
transparent MRI head

wind flow

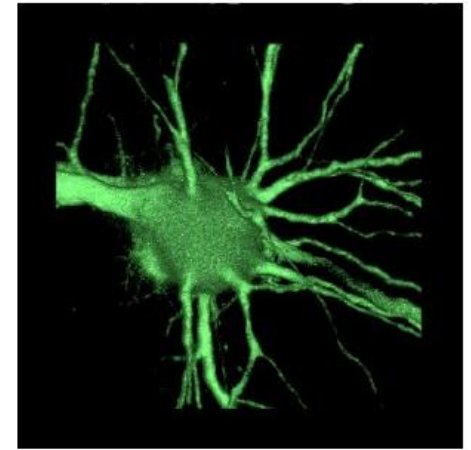
semi-transparent  
tomato

MRI head

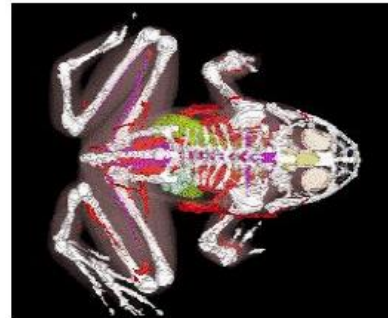
# SPATIAL DATA



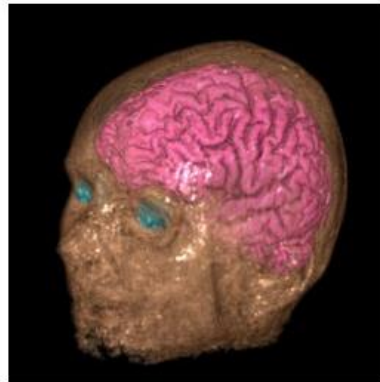
shock wave



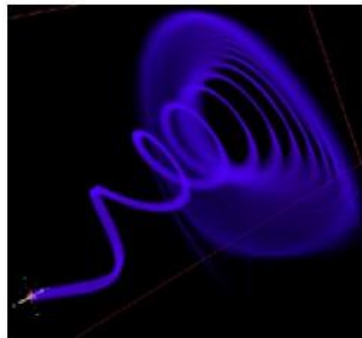
nerve cell



virtual frog



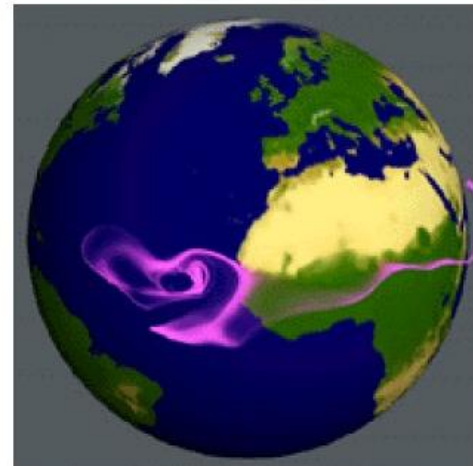
transparent MRI head



spiral flow



semi-transparent  
tomato



wind flow



MRI head

# SPATIAL DATA

Example: Datasets obtained by 3D volumetric scans (CT, MRI)

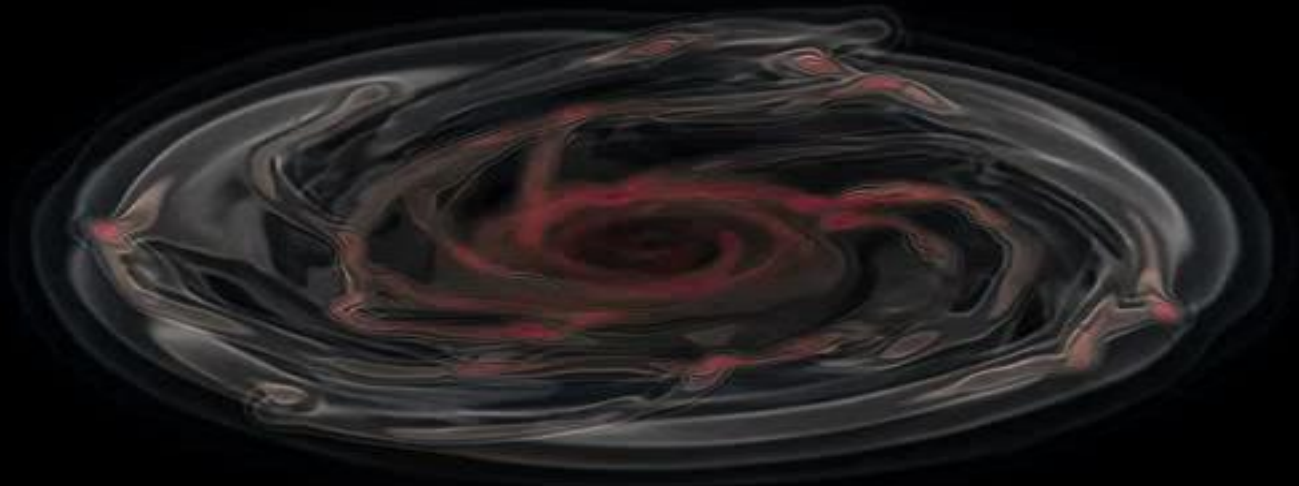
- what are some questions you might have?



# SPATIAL DATA

Example: Datasets obtained by 3D Simulations

- what are some questions you might have?



# SPATIAL DATA

Example: Data obtained by observation-supported simulations

- what are some questions you might have?

# NON-SPATIAL DATA

The salient features of a car:

- miles per gallon (MPG)
- top speed
- acceleration
- number of cylinders
- horsepower
- weight
- year
- country origin
- brand
- number of seats
- number of doors
- reliability (# of breakdowns)
- and so on...





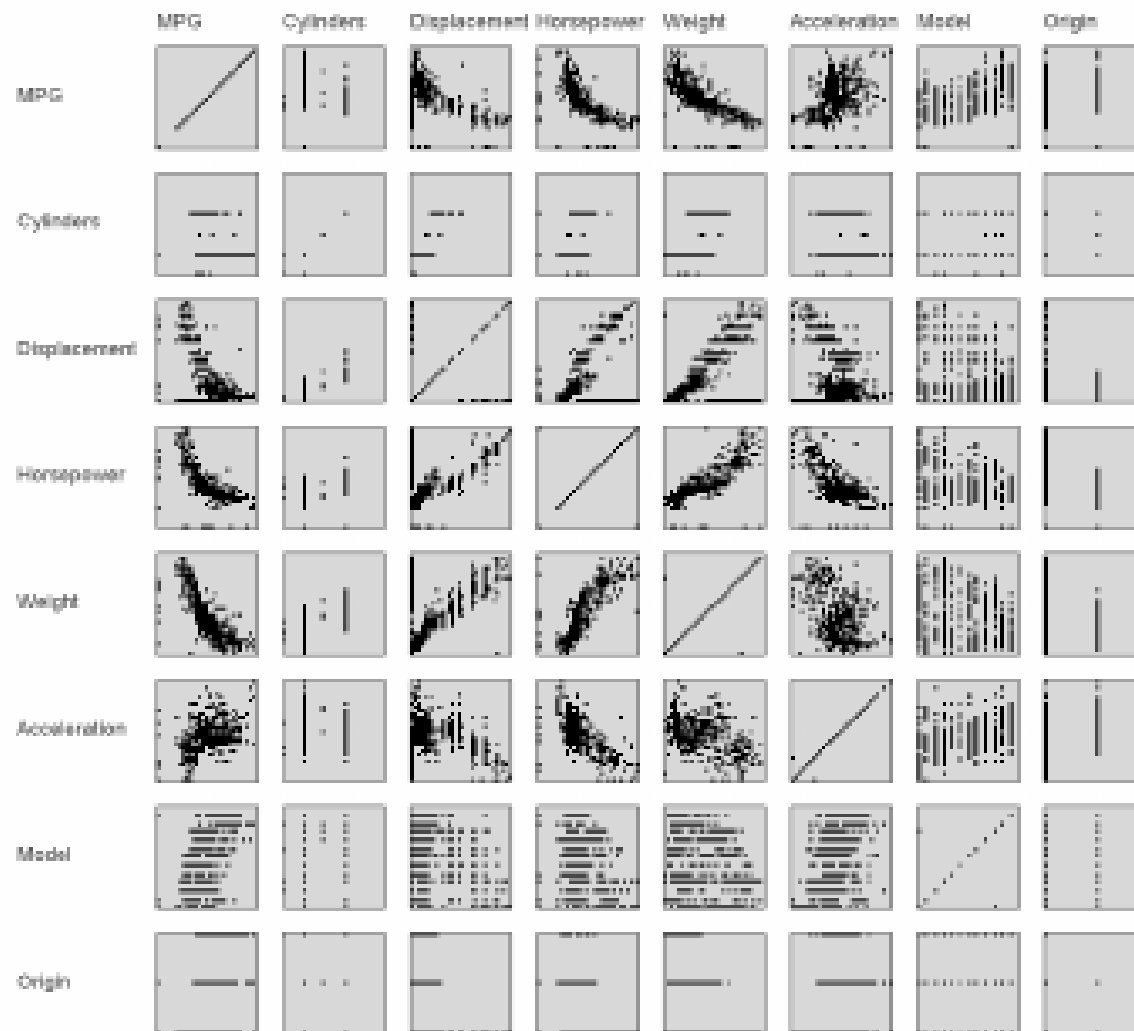
# CAN YOU VISUALIZE THEM LIKE THIS?

A1		Urban population														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Urban population	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
2	Afghanistan	769308	811389	855131	900646	948060	997499	1053104	1110728	1170961	1234664	1302370	1391081	1483942	1579748	1676656
3	Albania	494443	511637	529182	547024	565117	583422	601897	620508	639234	658062	676985	698179	719561	741149	762972
4	Algeria	3293999	3513320	3737362	3969886	4216744	4483048	4644898	4822860	5015071	5218184	5429743	5618190	5813978	6017932	6231383
5	American Samoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Andorra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Angola	521205	552777	585121	618345	652638	688181	729595	772643	817418	863993	912486	982944	1056617	1133936	1215437
8	Antigua and Barbuda	21699	21737	21878	22086	22309	22513	22717	22893	23053	23218	23394	24046	24718	25342	25826
9	Argentina	15224096	15588864	15957125	16328045	16700303	17073371	17432905	17793789	18160868	18540720	18938137	19335571	19750609	20180707	20621674
10	Armenia	957974	1008899	1061551	1115546	1170414	1225785	1281346	1337060	1393199	1450241	1508526	1565054	1622558	1680709	1739019
11	Aruba	24996	25514	26019	26498	26941	27337	27683	27984	28247	28491	28726	28959	29188	29409	29610
12	Australia	8375329	8585577	8840666	9055650	9279777	9508980	9770529	9937118	10157212	10416192	10668471	11050785	11271606	11461308	11771589
13	Austria	4560057	4589541	4621666	4653194	4685421	4715750	4754585	4778506	4798552	4817322	4849178	4871380	4904030	4932109	4939292
14	Azerbaijan	1857673	1929429	2004258	2080816	2157307	2232355	2306310	2378380	2448728	2517815	2586000	2660687	2734631	2807879	2880491
15	Bahamas	65457	69655	74179	78961	83902	88918	93931	98974	103944	108721	113219	117339	121142	124761	128393
16	Bahrain	128480	133815	139791	146052	152097	157596	162844	167630	172373	177677	183997	191379	199768	209201	219678
17	Bangladesh	2761049	2947191	3141372	3344120	3556037	3777716	4047121	4329144	4624445	4933701	5257558	5710277	6184871	6682073	7202503
18	Barbados	84884	85284	85761	86285	86797	87259	87707	88117	88526	88986	89532	90518	91596	92713	93796
19	Belarus	2656152	2774166	2896449	3022217	3150553	3280410	3415984	3554673	3695363	3836802	3977600	4131179	4285735	4439788	4591705
20	Belgium	8435075	8489549	8548773	8620194	8709437	8796088	8865259	8924327	8968568	9003536	9040444	9086816	9134227	9175144	9217085
21	Belize	49165	50608	52156	53734	55226	56561	57756	58820	59746	60532	61186	61883	62445	62984	63665
22	Benin	211033	229172	248065	267765	288321	309788	332782	366019	396065	427482	460341	500355	542251	586179	632320
23	Bermuda	44400	45500	46600	47700	48900	50100	51000	52000	53000	54000	55000	56000	57000	58000	59000
24	Bhutan	8064	8778	9526	10311	11137	12010	13089	14230	15445	16750	18158	19926	21827	23858	26008
25	Bolivia	1233398	1271250	1310294	1350615	1392328	1435536	1480255	1526529	1574517	1624419	1676370	1730434	1786553	1844596	1904355
26	Bosnia and Herzegovi	604204	637337	671124	705395	739884	774380	812856	851325	890011	929301	969514	1008688	1048890	1089898	1131315
27	Botswana	16240	17379	18583	19855	21203	22631	28191	34090	40352	46995	54038	61638	69689	78254	87422
28	Brazil	32662018	34463344	36353068	38320171	40346703	42418482	44548227	46722996	48945984	51223962	53563179	56042505	58587770	61207586	63913385
29	Brunei	35501	38753	42173	45802	49699	53916	58461	63355	68595	74157	80024	83802	87671	91616	95629
30	Bulgaria	2918659	3085061	3251675	3418610	3588246	3756058	3889518	4022040	4159890	4301340	4440270	4554810	4667059	4782931	4907107
31	Burkina Faso	221872	230199	238713	247472	256558	266039	275958	286311	297074	308196	319642	332556	345877	359655	373966
32	Burundi	58810	61055	63344	65696	68137	70683	73370	76186	79034	81779	84324	86879	89308	91757	94204
33	Cambodia	559631	578678	598248	618631	640243	663272	687219	712179	738138	764107	790076	816045	842014	867983	893952
34	Cameroon	751711	801009	852578	906523	962928	1021891	1088521	1158289	1231375	1307967	1388275	1472958	1564410	1654410	1749385
35	Canada	12375125	12764121	13145207	13536503	13941055	14345262	14727261	15108962	15470875	15800439	16142268	16381341	16640381	16920220	17221765
36	Cape Verde	32791	34353	35972	37672	39487	41435	43592	45884	48200	50383	52314	54103	55620	56940	58184
37	Cayman Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	Central African Rep.	302157	317715	333986	351001	368787	387357	408129	429825	452326	475441	499036	526414	554452	583376	613530
39	Chad	198777	213406	228652	244499	260903	277834	305390	333898	363523	394530	427153	467662	510348	554973	601045
40	Channel Islands	42565	42665	42792	42941	43102	43269	43437	43604	43765	43916	44051	44208	44387	44587	44792

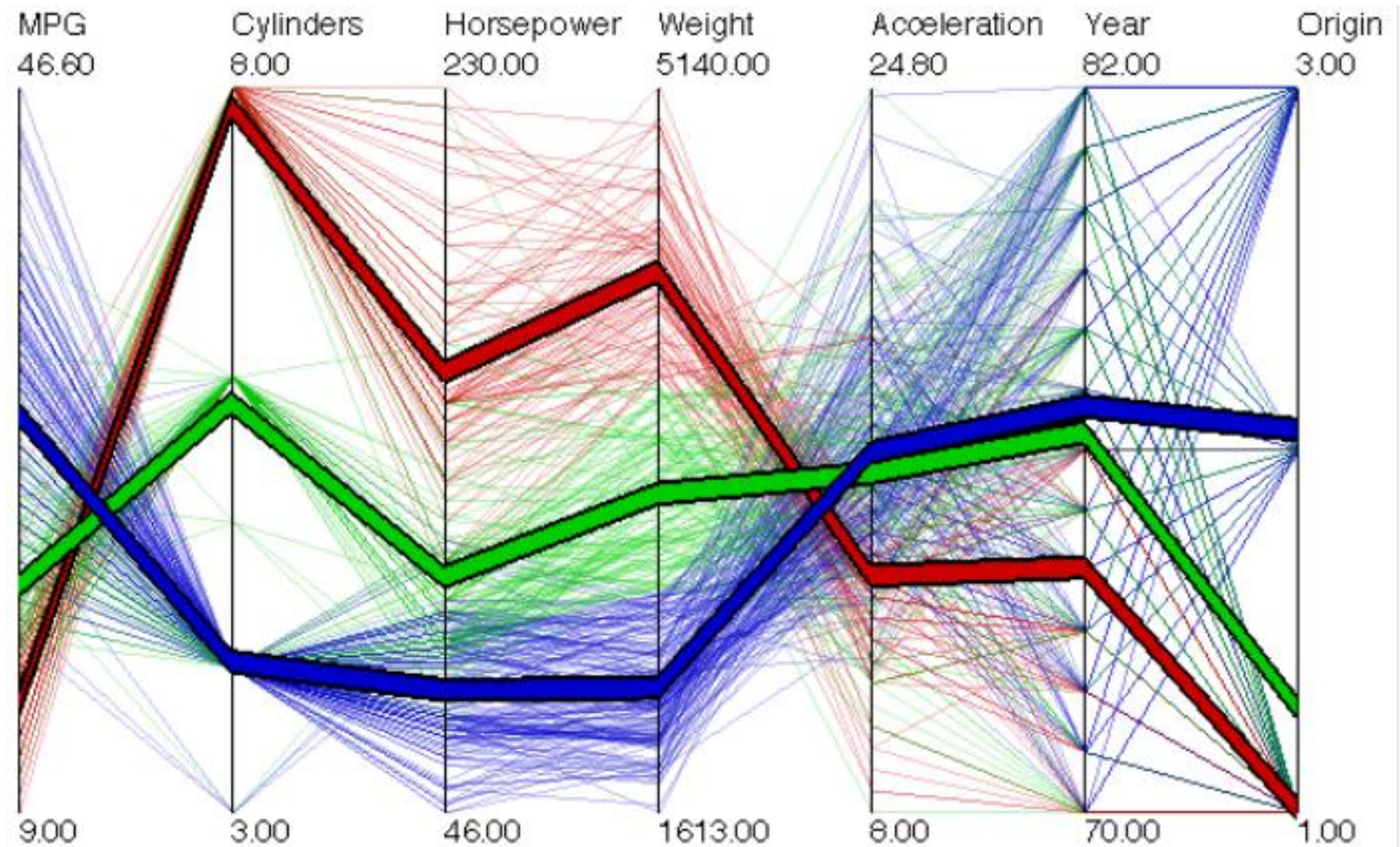
How are MPG, weight, HP, and reliability related? Are there tradeoffs?  
Which car is best for me?



# “BASIC” VISUALIZATION – MANY BIVARIATE PLOTS (SCATTER PLOT MATRIX)



# ADVANCED VISUALIZATION – PARALLEL COORDINATES



# BIG DATA

**12+ TBs**  
of tweet data  
every day



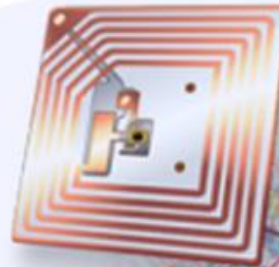
**25+ TBs** of  
log data every day



**? TBs** of  
data every day



**30 billion** RFID  
tags today  
(1.3B in 2005)



**76 million** smart  
meters in 2009...  
200M by 2014

**4.6 billion**  
camera  
phones  
world wide



**100s of millions**  
of GPS  
enabled  
devices  
sold  
annually

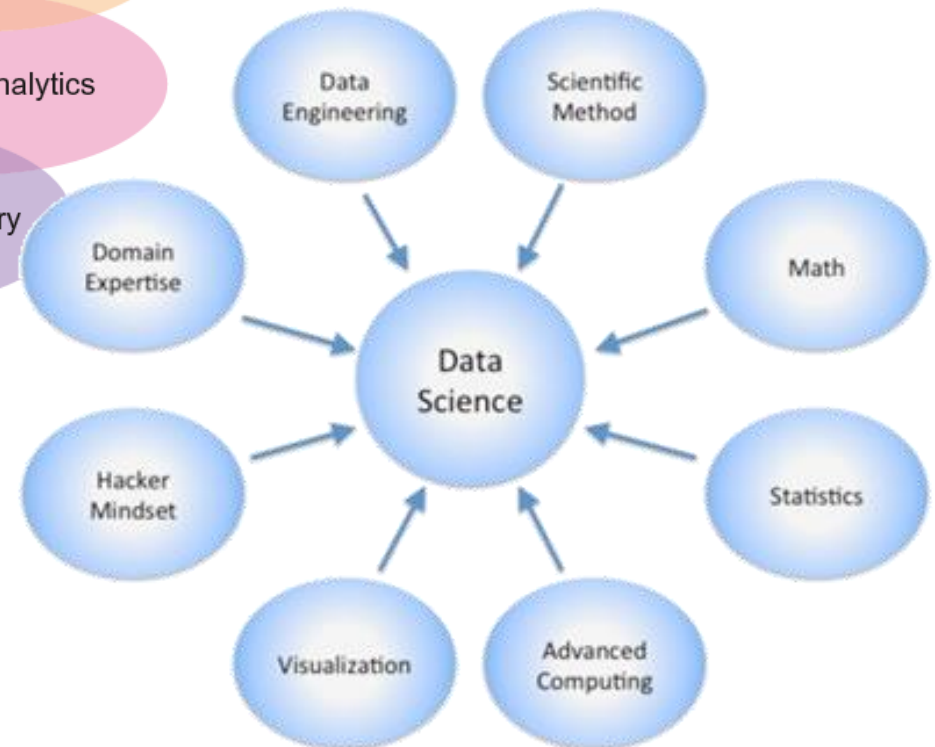
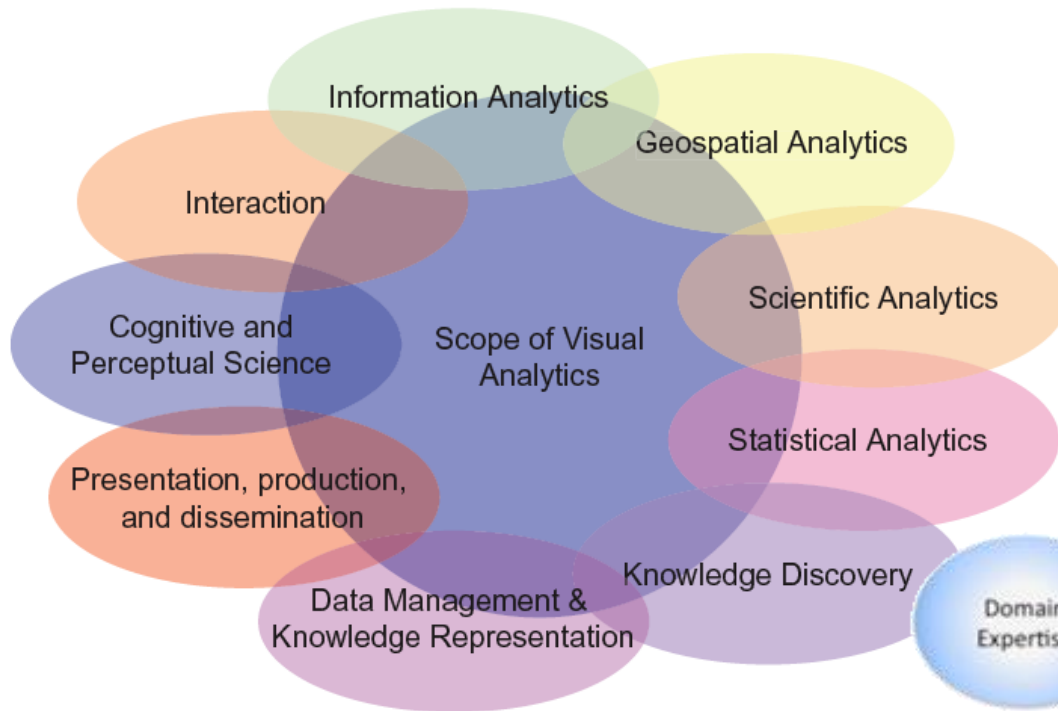


**2+ billion**  
people on  
the Web  
by end  
2011





# VISUAL ANALYTICS VS. DATA SCIENCE



# MODERN DATA SCIENTIST

21st century, requires a mixture of multidisciplinary skills ranging from computer science, communication, and business. The modern data scientist really is a data scientist who is equally happy to communicate and collaborate.

## MATH & STATISTICS

- ☆ Machine learning
- ☆ Statistical modeling
- ☆ Experiment design
- ☆ Bayesian inference
- ☆ Supervised learning: decision trees, random forests, logistic regression

## DOMAIN KNOWLEDGE & SOFT SKILLS

- ☆ Passionate about the business
- ☆ Curious about data
- ☆ Influence without authority
- ☆ Hacker mindset
- ☆ Problem solver
- ☆ Strategic, proactive, creative, innovative and collaborative

## PROGRAMMING & DATABASE

- ☆ Computer science fundamentals
- ☆ Scripting language e.g. Python
- ☆ Statistical computing packages, e.g., R
- ☆ Databases: SQL and NoSQL
- ☆ Relational algebra
- ☆ Parallel databases and parallel query

## COMMUNICATION & VISUALIZATION

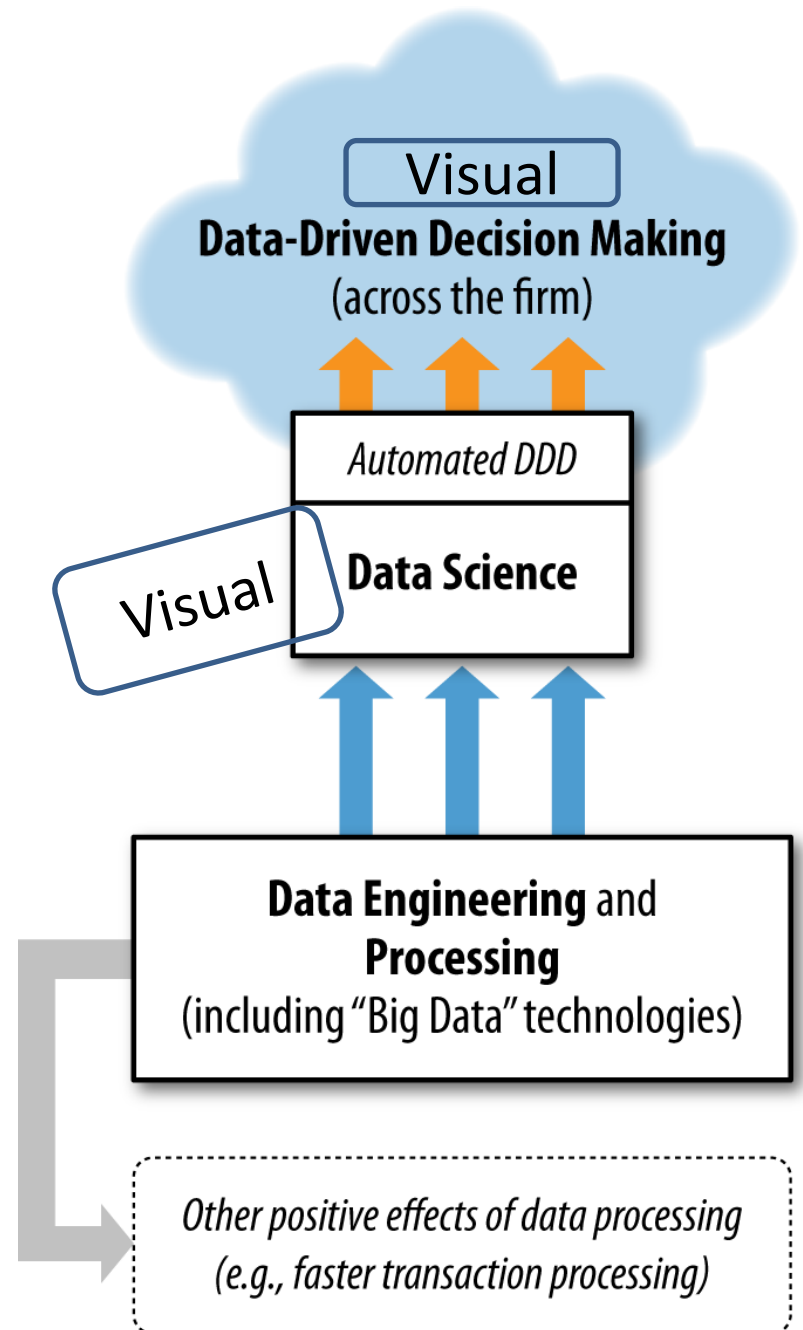
- ☆ Able to engage with senior management
- ☆ Story telling skills
- ☆ Translate data-driven insights into decisions and actions
- ☆ Visual art design
- ☆ R packages like ggplot or lattice
- ☆ Knowledge of any of visualization tools e.g. Flare, D3.js, Tableau



# VDDD =

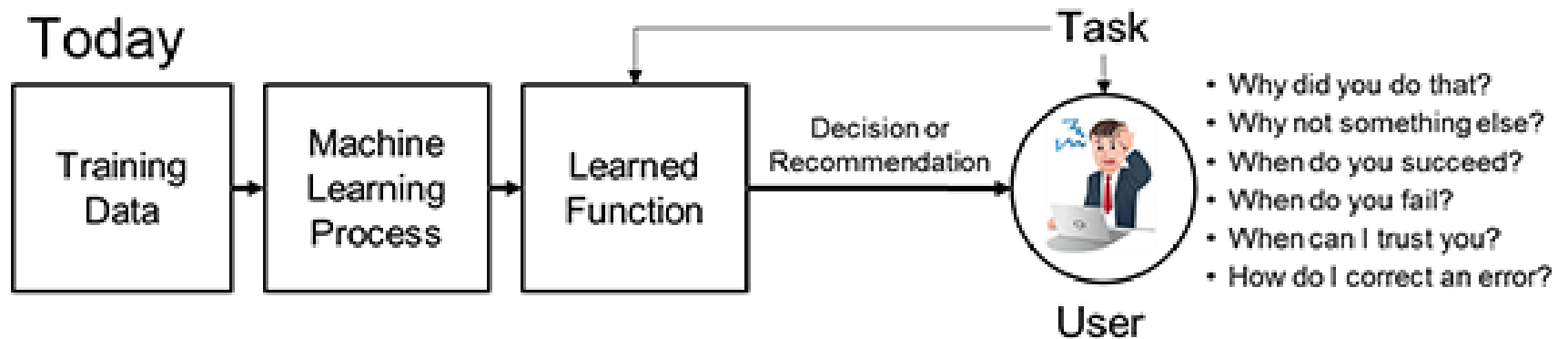
Make decisions based on data

- not purely on intuition and long business experience
- use a combination of these

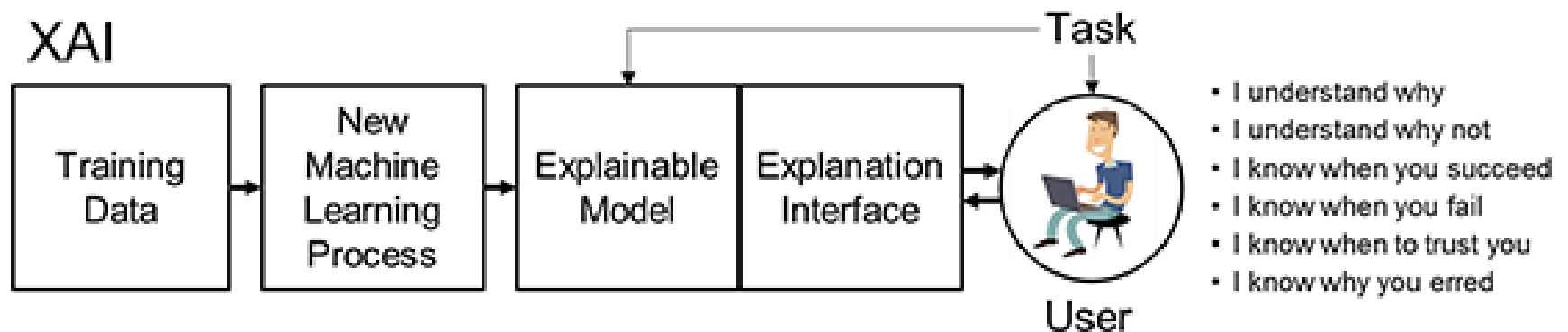


# EXPLAINABLE AI (XAI)

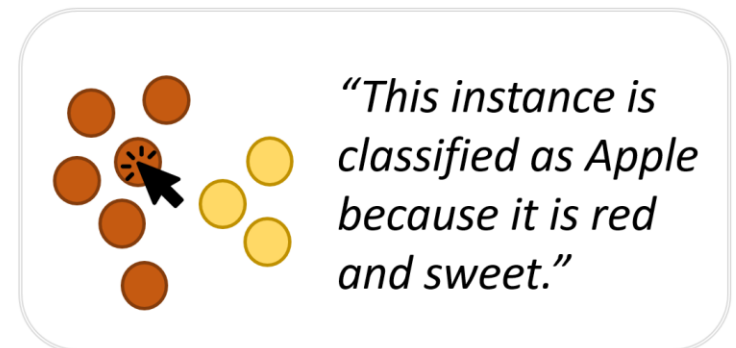
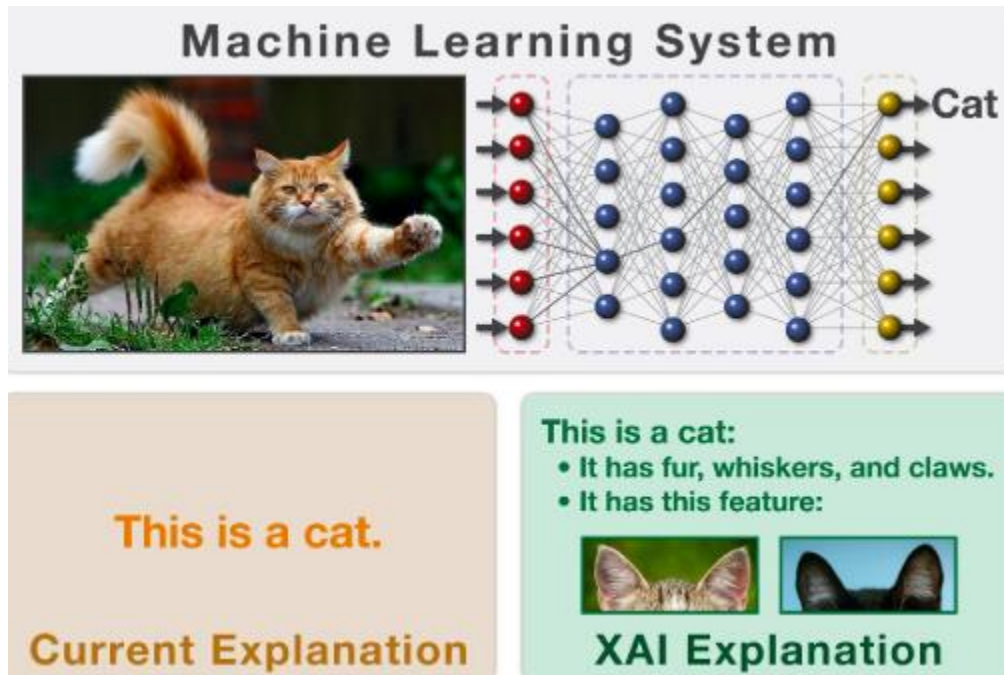
## Today



## XAI



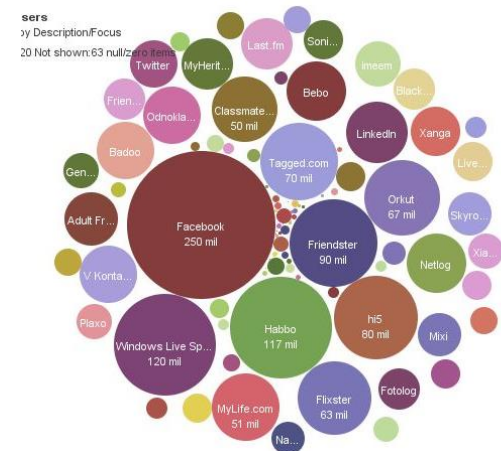
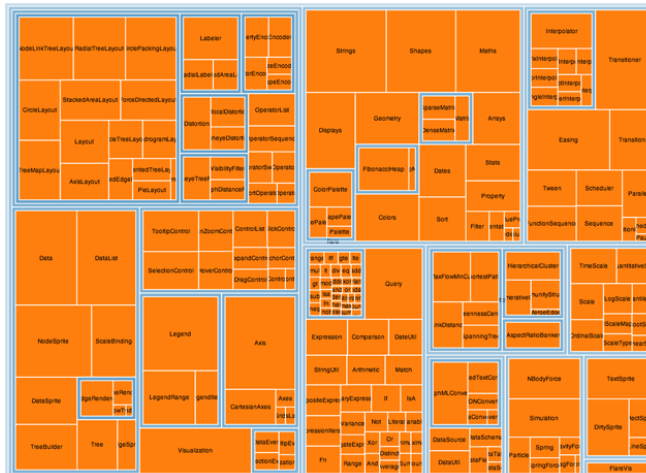
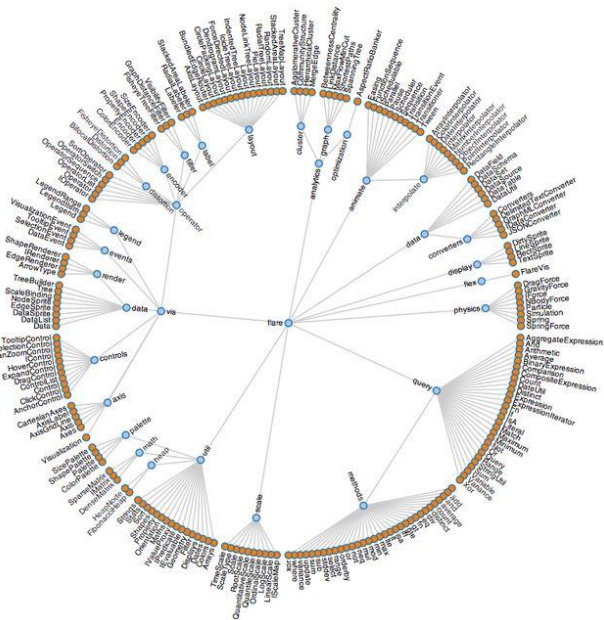
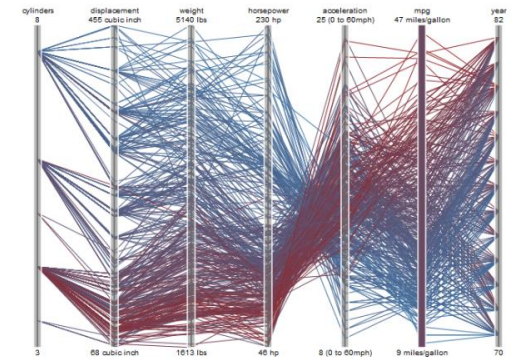
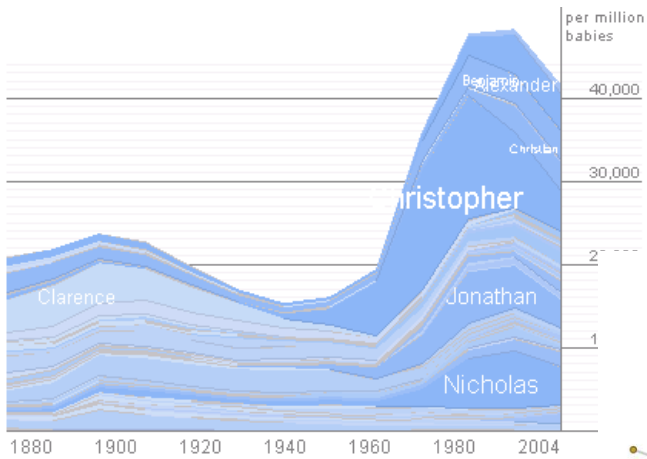
# EXPLAINABLE AI (XAI)





VISUALIZATION CAN BE BEAUTIFUL

# VISUALIZATION CAN BE BEAUTIFUL



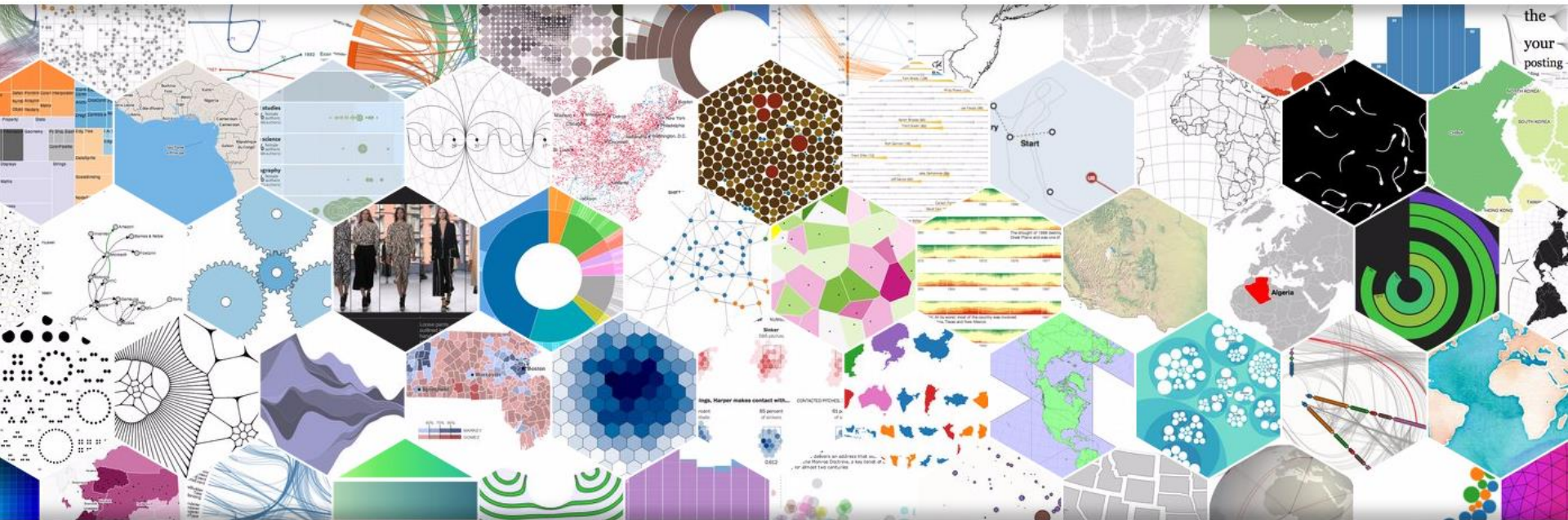
# VISUALIZATION CAN BE INTERACTIVE

[D3 Demo](#)

[Overview](#) [Examples](#) [Documentation](#) [Source](#)

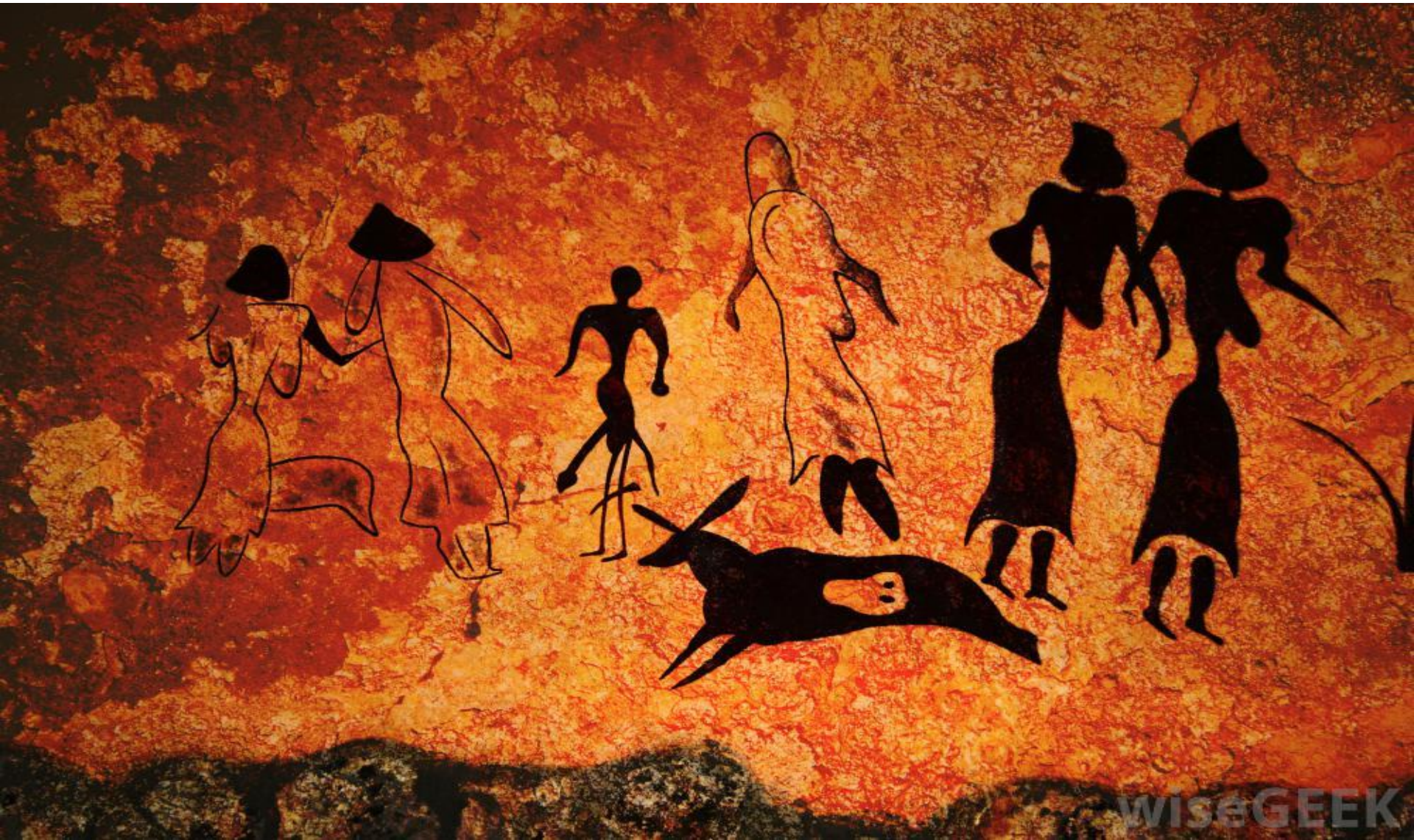


Fork me on GitHub



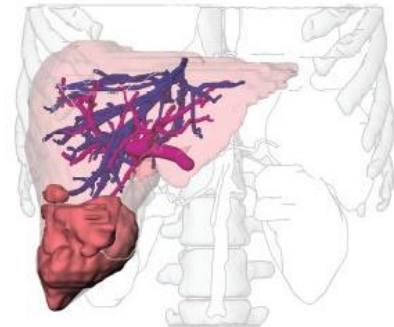
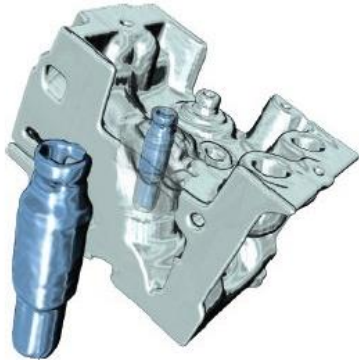
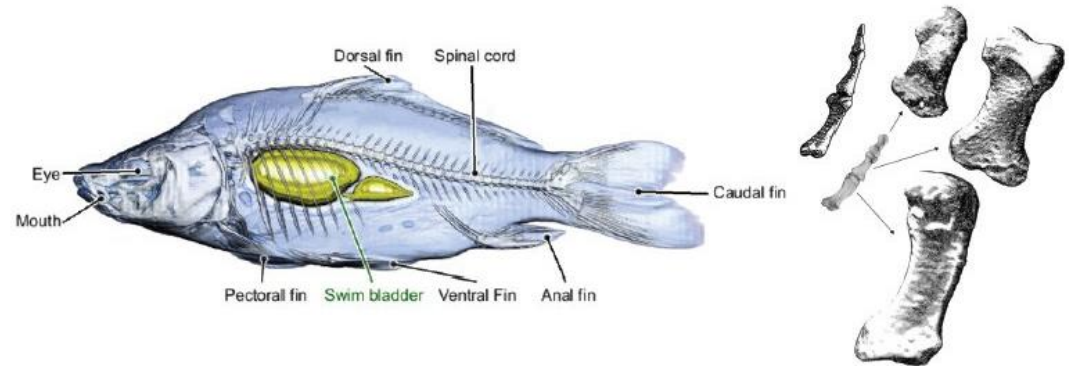


# VISUALIZATION HAS A LONG HISTORY

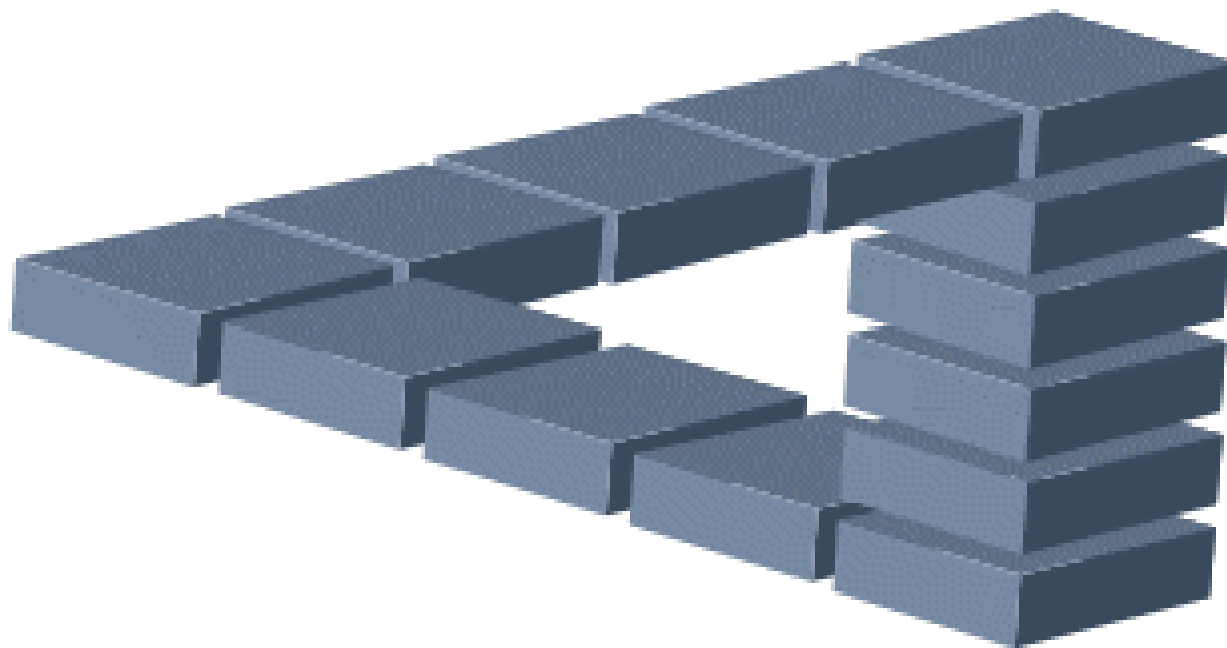




# VISUALIZATION CAN BE INSPIRED BY ART



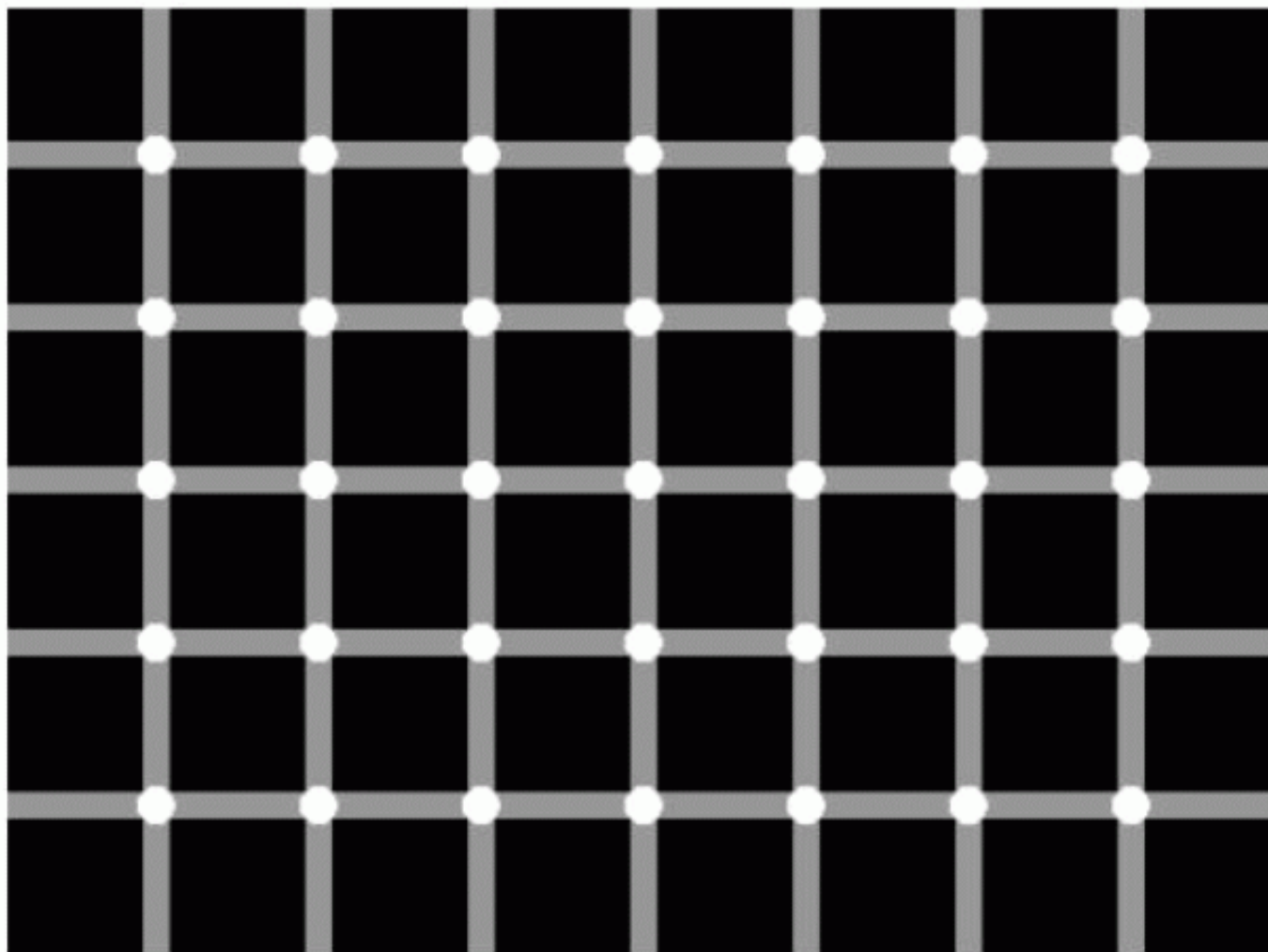
# VISUALIZATION CAN BE DECEPTIVE



# VISUALIZATION CAN BE DECEPTIVE



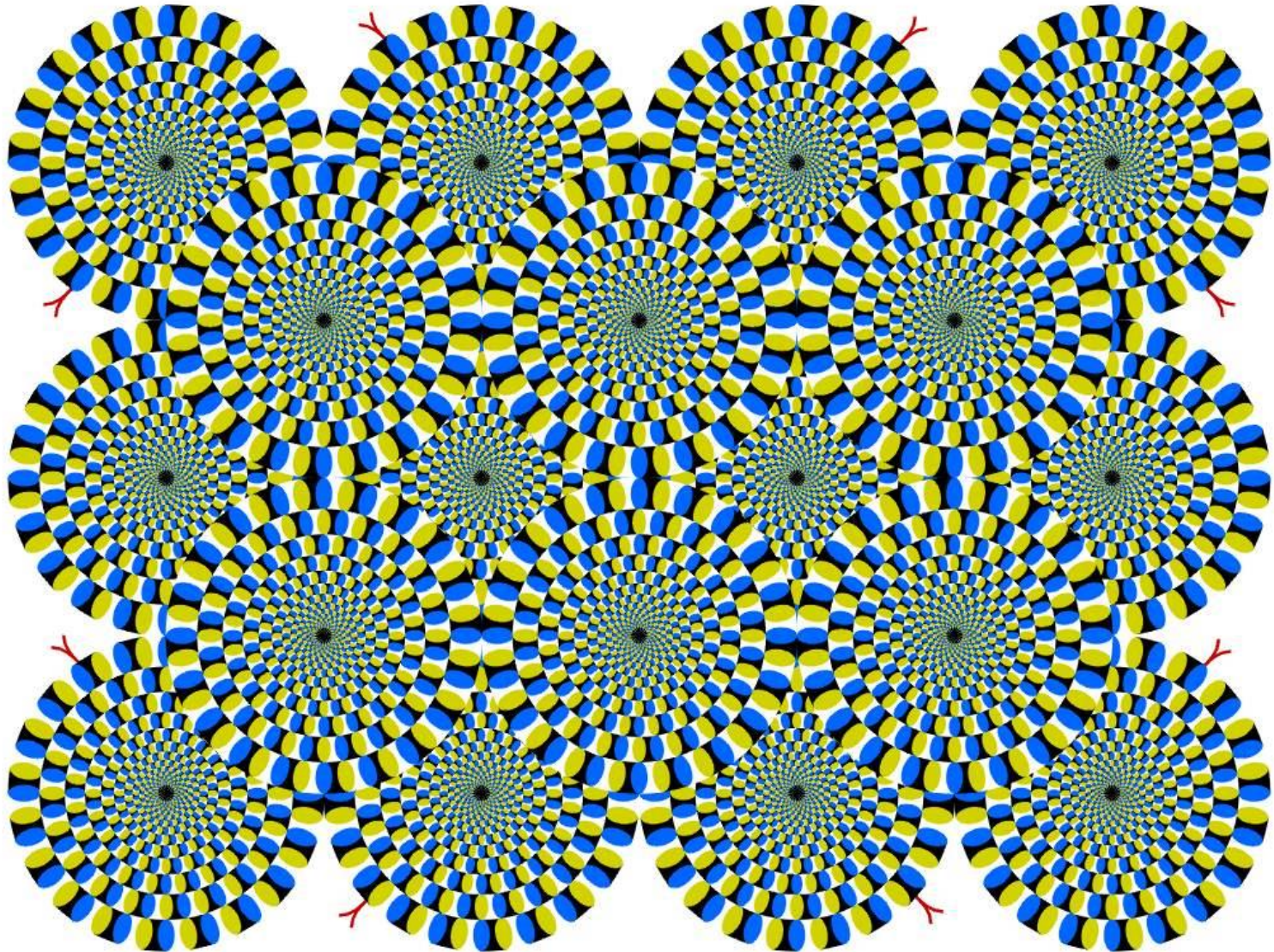
# VISUALIZATION CAN BE DECEPTIVE



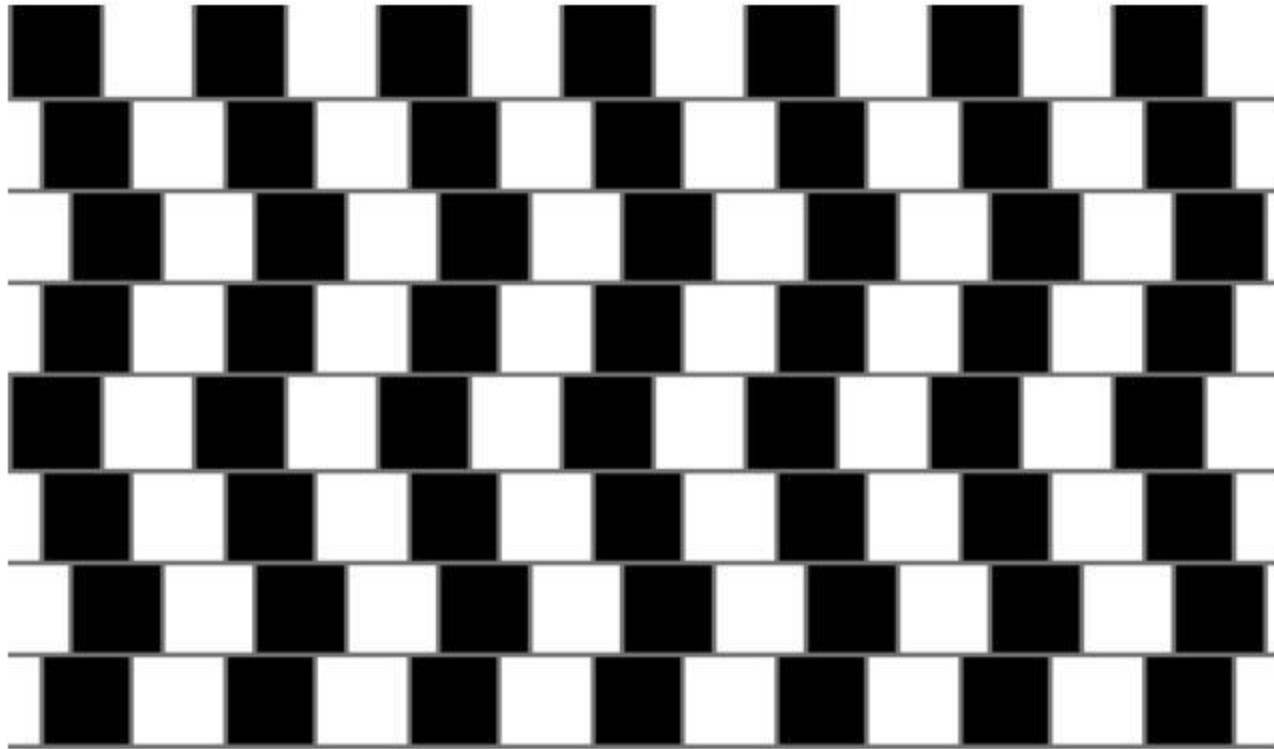
Count the number of black dots



# VISUALIZATION CAN BE DECEPTIVE

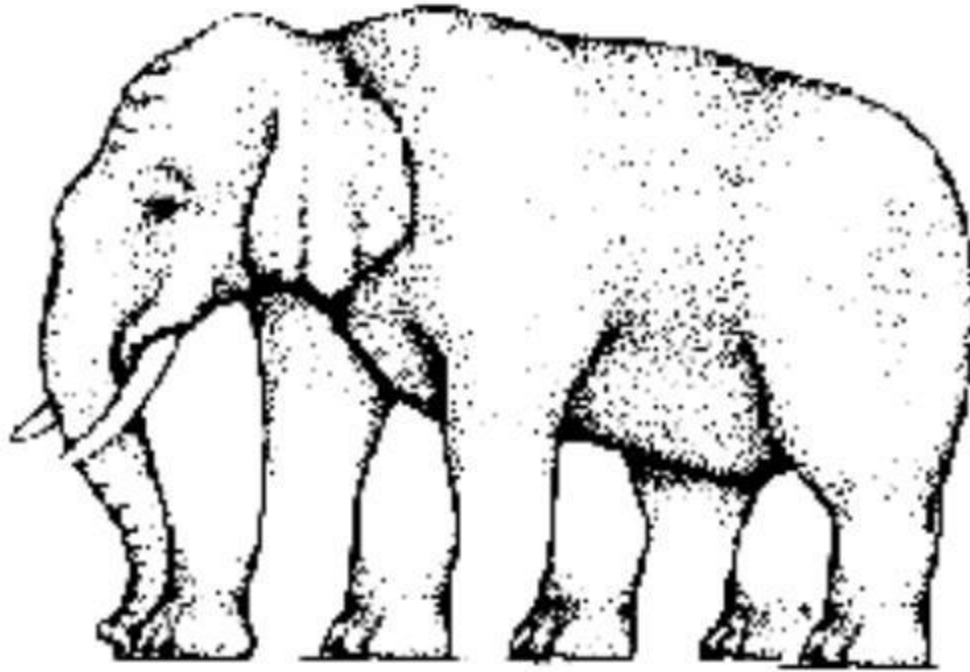


# VISUALIZATION CAN BE DECEPTIVE



Are the horizontal lines parallel or do they slope?

# VISUALIZATION CAN BE DECEPTIVE



How many legs does this elephant have?



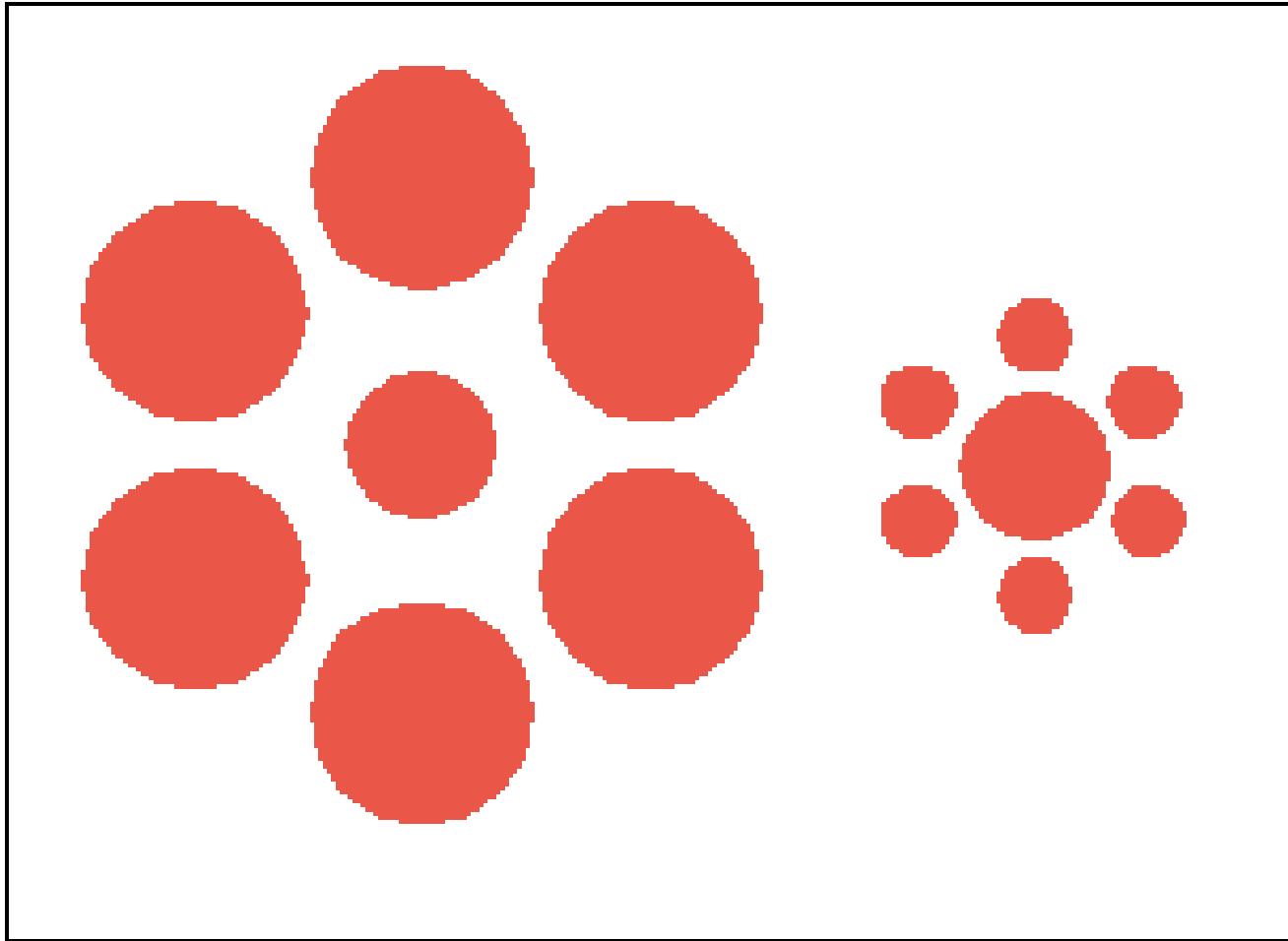
# VISUALIZATION CAN BE DECEPTIVE



Julian Beever



# VISUALIZATION CAN BE DECEPTIVE

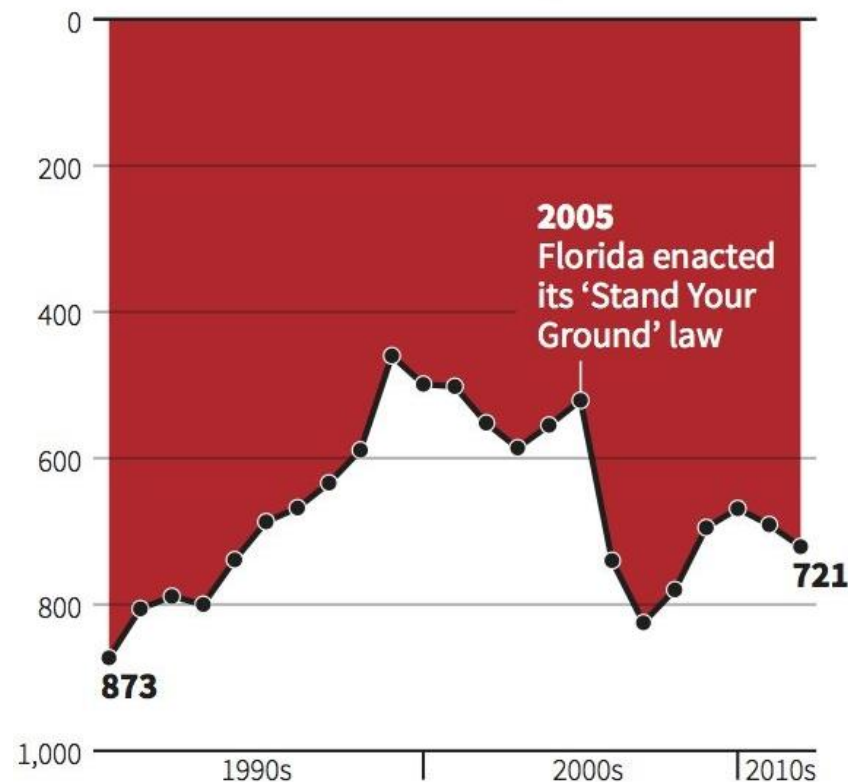


**Which circle in the middle is bigger?**

# VISUALIZATION CAN BE DECEPTIVE

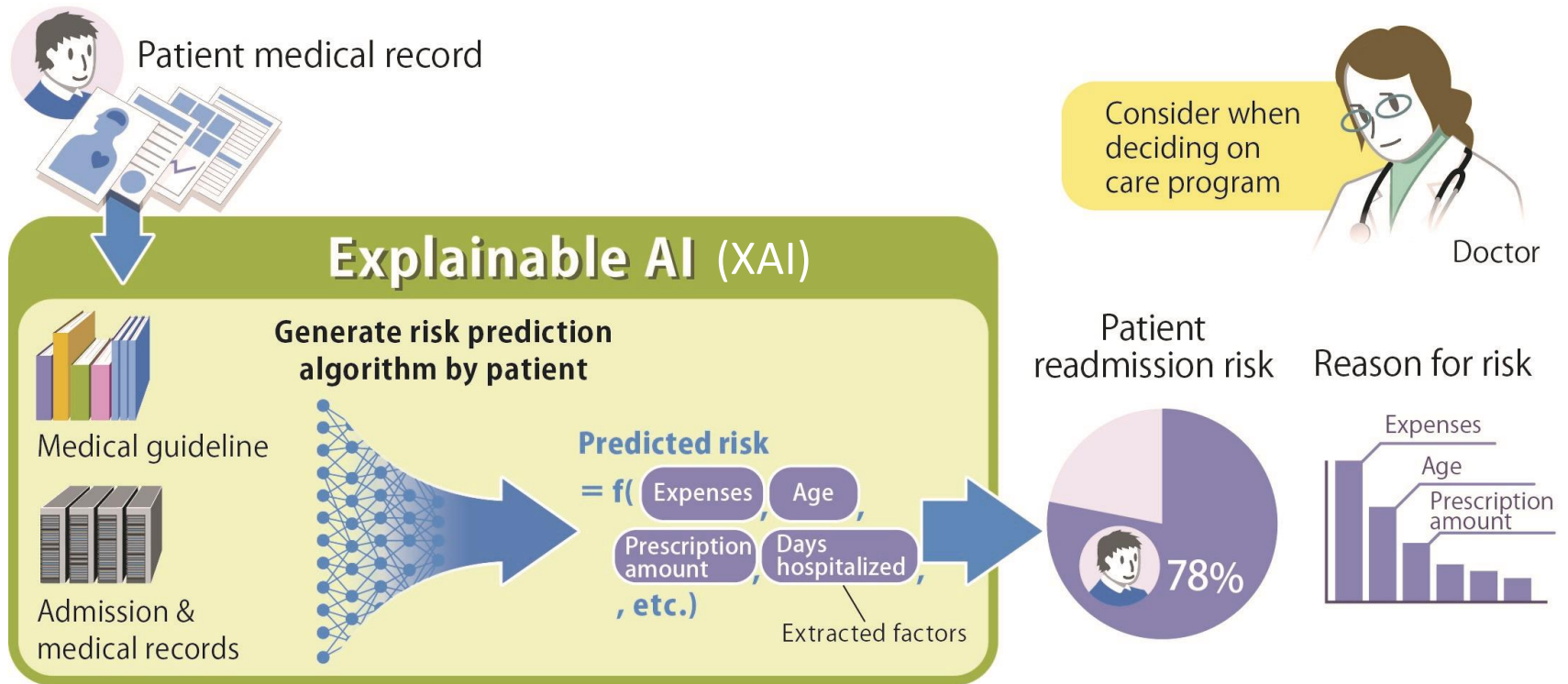
## Gun deaths in Florida

Number of murders committed using firearms



Source: Florida Department of Law Enforcement

# VISUALIZATION CAN BE ENABLING



Visualization can establish trust

# THE POWER OF THE VISUAL SYSTEM

The human visual system is not perfect, but it's extremely powerful

Vision is an integral part of life

Vision is the gateway to higher-level regions of the brain

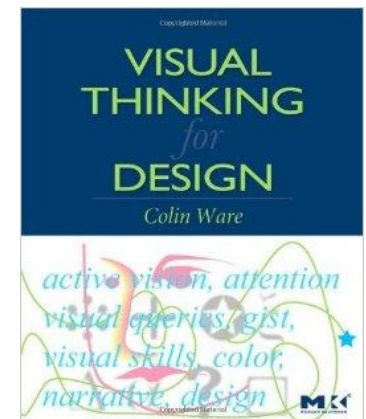
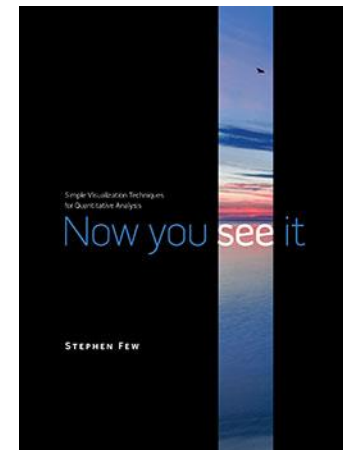
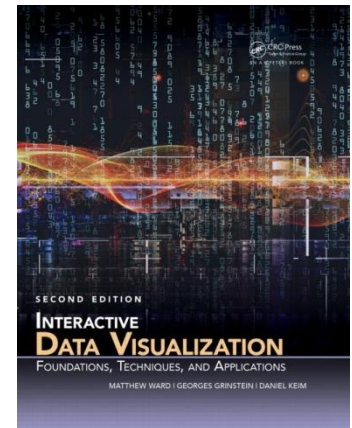
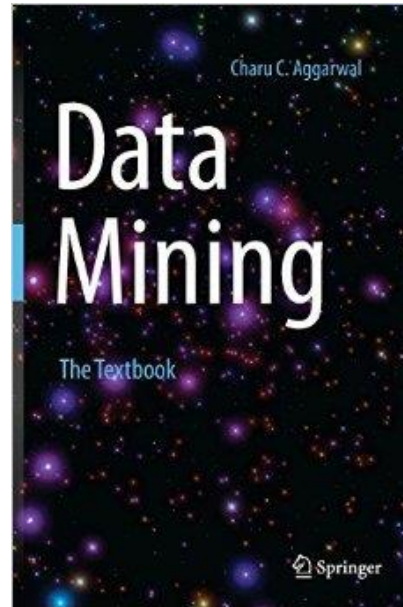
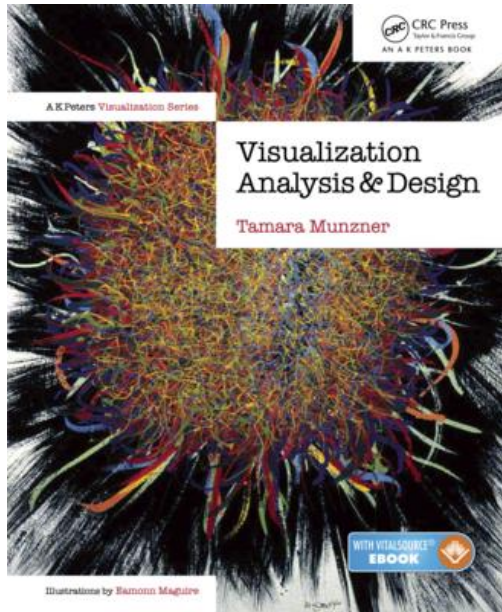
Exploit this fast and powerful processor for

- complex data analyses, creative tasks, communicating ideas

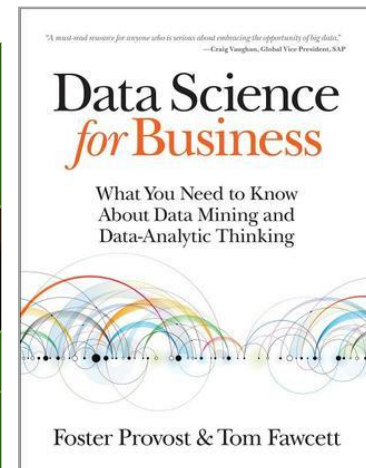
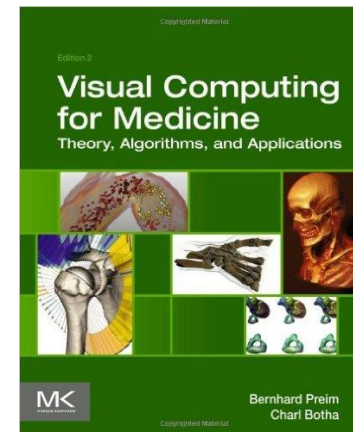
→ The science of visualization and visual analytics



# TEXT BOOKS



Required



Optional

# TENTATIVE SCHEDULE

Lecture	Topic	Projects
1	Intro, schedule, and logistics	
2	Applications of visual analytics, data types	
3	Basic tasks	Project 1 out
4	Data preparation and representation	
5	Data reduction, notion of similarity and distance	
6	Dimension reduction	
7	Introduction to D3	Project 2 out
8	Visual perception and cognition	
9	Visual design and aesthetic	
10	Visual analytics tasks	
11	Cluster analysis	
12	High-dimensional data, dimensionality reduction	
13	Visualization of spatial data: volume visualization intro	Project 3 out
14	Introduction to GPU programming	
15	Visualization of spatial data: raycasting, transfer functions	
16	Illumination and isosurface rendering	
17	Midterm	
18	Scientific visualization	
19	Non-photorealistic and illustrative rendering	Project 4 out
20	Midterm discussion	
21	Principles of interaction	
22	Visual analytics and the visual sense making process	
23	Visualization of graphs and hierarchies	
24	Visualization of time-varying and streaming data	Project 5 out
25	Maps	
26	Memorable visualizations, visual embellishments	
27	Evaluation and user studies	
28	Narrative visualization, storytelling, data journalism, XAI	

# GRADING CSE 332

Midterm (1<sup>st</sup> part of the course): 30%

Final (2<sup>nd</sup> part of the course): 40%

Projects (5): 30%

choose wisely



- propose a dataset DS and argue why you think it's interesting (5%)
- code up a set of basic interactive D3.js visualizations for DS (5%)
- implement a set of advanced interactive D3.js visualizations (5%)
- interlude: create some spatial visualizations using ImageVis3D (5%)
- create an interactive D3.js visual analytics dashboard (10%)

Participation:

- not mandatory, but desired (lectures will be recorded)

For late submission policy see [course website](#)

- course website will publish all course materials