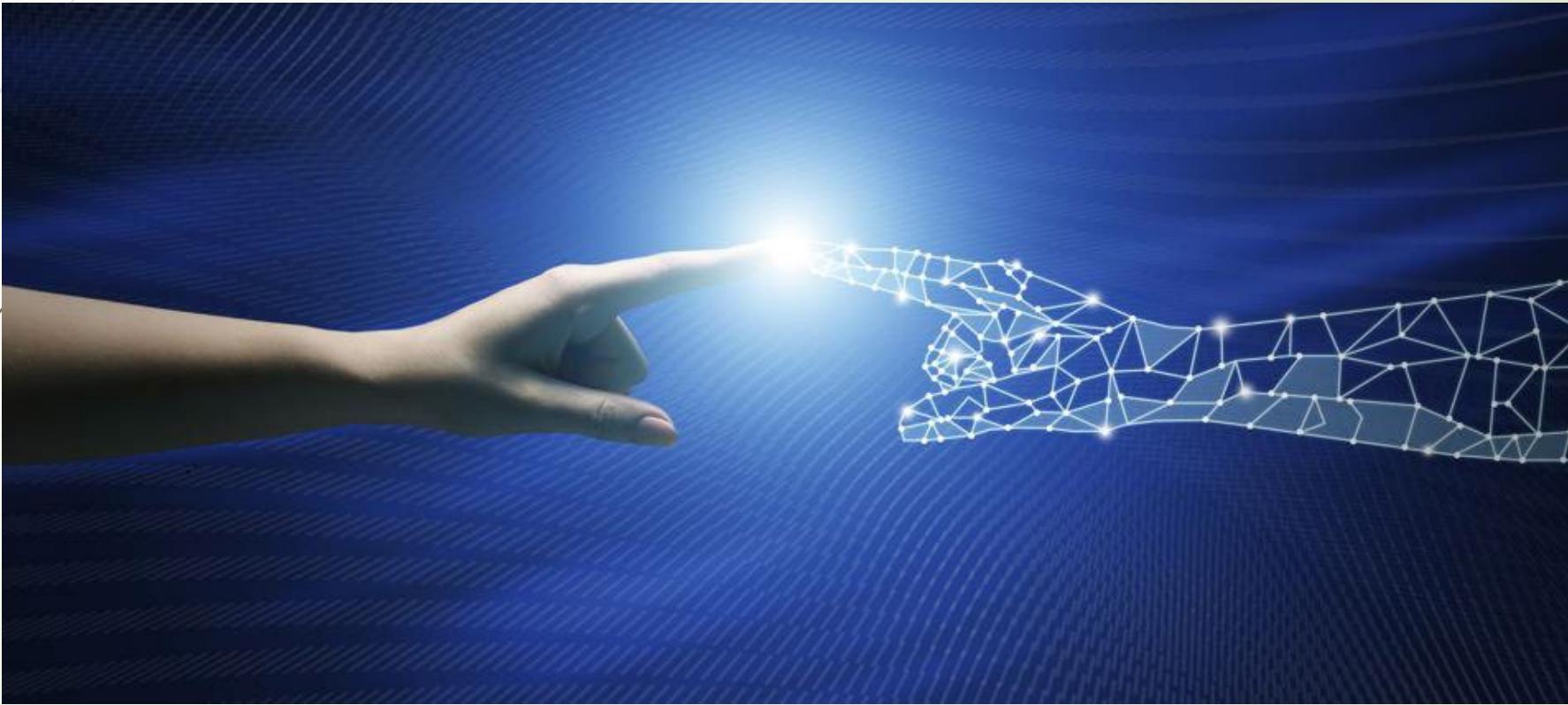


AI & Statistical Machine Learning





What is AI

AI = Artificial Intelligence

Artificial:

- made by human beings rather than occurring naturally

Intelligence:

- capacity for learning, reasoning, understanding
- aptitude in grasping truths, relationships, facts, meanings, etc.

Artificial Intelligence

- recreate the human-thought process
 - build a man-made machine with intellectual abilities.
-
- 1956, John McCarthy organized a summer conference titled “Artificial Intelligence” at Dartmouth University.
 - 70's– 90's, U.S. and British Governments stopped funding undirected research in AI. “AI Winter”
 - 21st Century, AI was successfully applied to a wide range of problems in academia and industries. (driven by powerful computers, innovative approaches, massive and big data)





What is A Robot



Programmable machines

- carry out a complex series of actions **automatically**.
- do repetitive (often boring) activity perfectly and objectively
- have extreme sensing (better eyes, ears) and power (strength and speed)
- unwavering focus (can not be distracted), can not get tired



Traditional Robots vs Modern AI

Traditional Robots:

- can only perform programmed tasks
- can not think or reason, perform complex human interactions, respond to unexpected situations

Modern AI:

- think, reason, formulate original idea
- solve problems, make decisions
- understand and use language; learn just about anything

AI for Smart Home

“OK, Google, turn off the lights, set the volume to five, and play my bedtime playlist”

“Alexa, what's the French word for 'French fries'?”

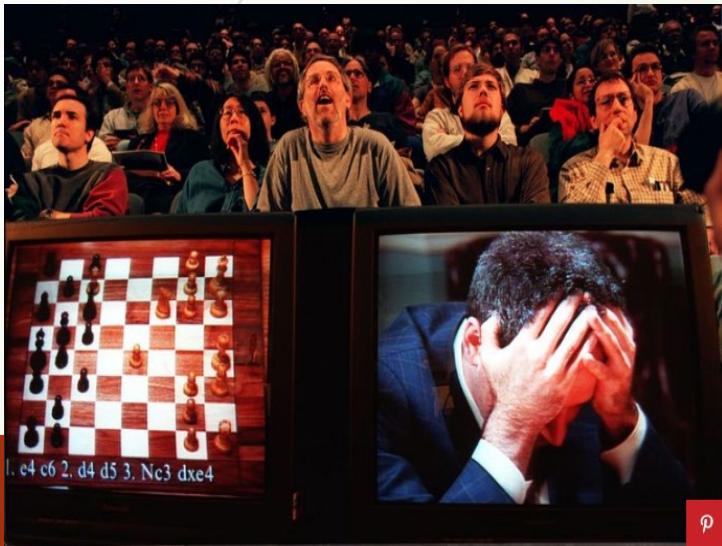


Google Nest Mini, Amazon Echo Dot



Apple Siri Speaker

Human-Computer Chess/Go Matches



Garry Kasparov
(world chess champion)
Vs
IBM's Deep Blue computer

Kasparov lost this match in just 19 moves (in the sixth and final match) 1997

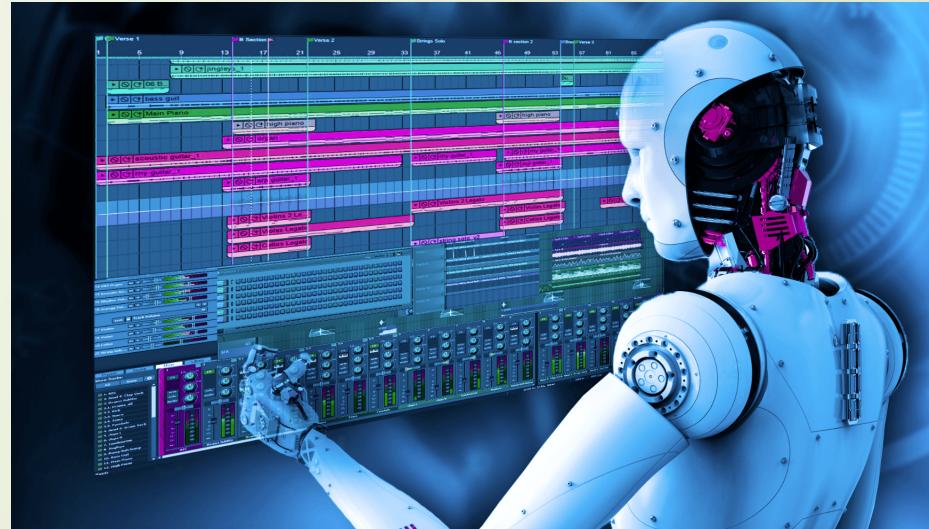


Chess programs running on commercial hardware are able to defeat even the strongest human players.

AI for Music



Wolfgang Mozart



Who is Emily Howell

Emily Howell

From Wikipedia, the free encyclopedia

Emily Howell is a computer program created by [David Cope](#),^[1] a music professor at the [University of California, Santa Cruz](#).^{[2][3]} derived from a previous composing program called **Experiments in Musical Intelligence (EMI)**.^[4] Cope attempts to “teach” the analysis.^[5]

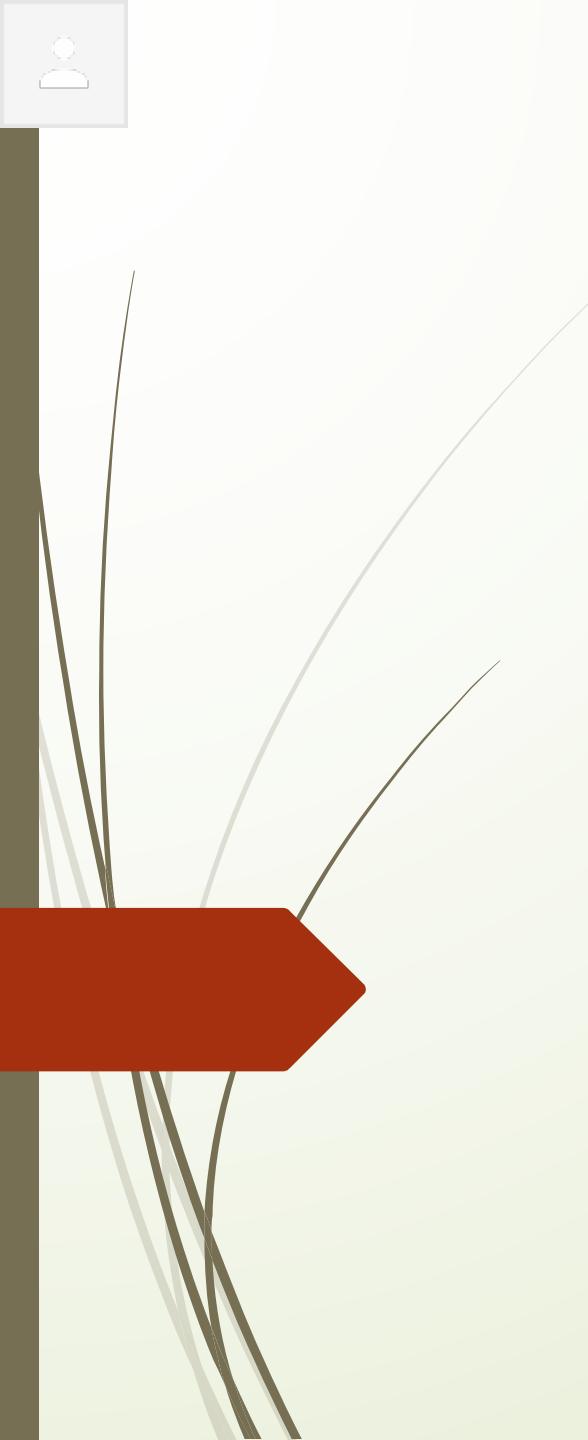


Emily Howell can

- compose music
- add personal style based on listeners feedback

Some AI's Biggest Achievements in 21st Century

- Natural Language Processing (NLP)
 - generate human language; produce text, HTML code, website; translation
- Healthcare and Drug Discovery AI
 - drug development, AlphaFold for protein structure
- Virtual assistance, security, surveillance technologies
 - face and speech recognition
- Self-driving cars
- Many more ...



How Does AI Work?





Operation of AI Systems

- First, ingest and analyze huge volumes of trained and labeled data for correlations and patterns;
- Second, use the patterns to forecast future events.

Examples:

- an image recognition tool can learn to identify and characterize items in photos by examining millions of samples.
- a chatbot can learn to make lifelike dialogues with people when being fed examples of text chats.



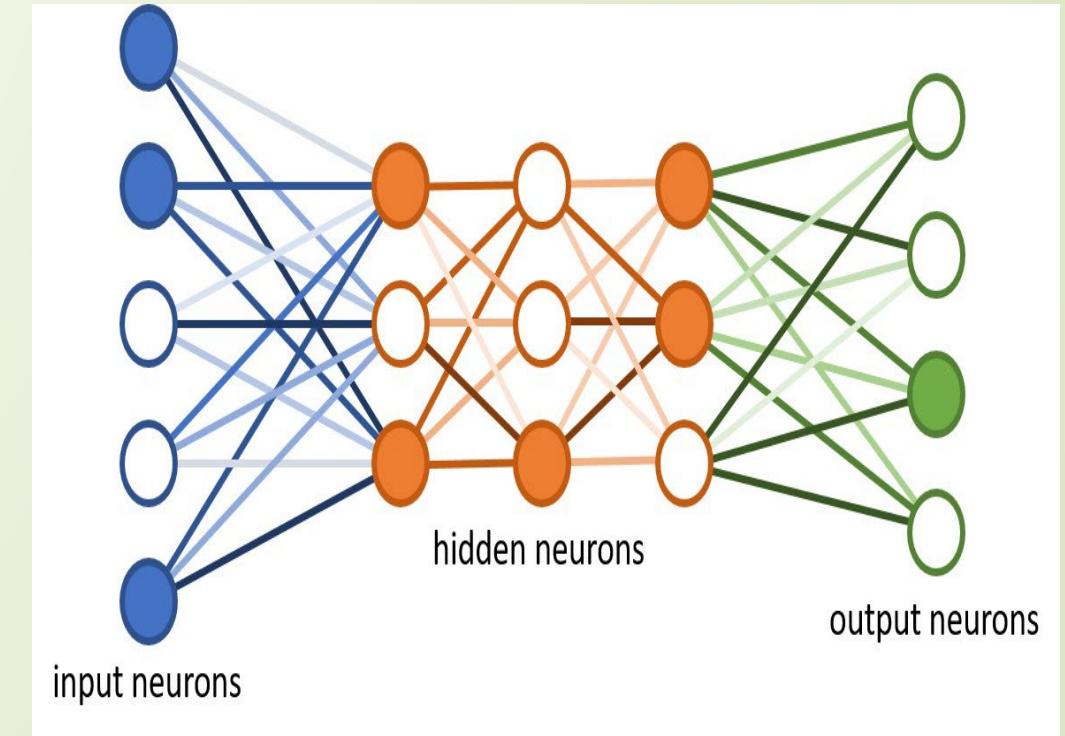
Key Components of AI

- Computers, optimization
- process big amount of data
- big memory, fast processors, scalable computation
- ***Statistical Machine Learning***
 - Use computer algorithms to build a mathematical model based on “data”, make predictions and decisions
- Engineering & Science (physics, biology, chemistry, economics, social science)
 - mimic human behaviors
 - how and why human learn and think

What is Neural Networks (NN)



Human Brain



Neural networks



Deep Reinforcement Learning

Human Chess Players

- Know the rule
- Calculate several steps (two-step checkmate)
- Guess the opponent's moves
- Compare different steps and make the best move
- Learn from mistakes

AlphaGo

Combines neural network and powerful search

- runs through various possible actions
- predicts which action gives the best result based on the collected information
- If a certain action gives a desired result, it stores this information and uses next time in the same situation (self-learning)





The Future of Automobiles

Human Drivers

- see the road and signs
- control the car movement (forward, backward, turns)
- adjust distance to other objects (moving cars, traffic light, pedestrian)
- react to emergent situations (accident, weather, broken parts)



Self-Driving Car Technology

- “See” with sensors
 - camera, GPS system, computer vision, laser light, radar, odometry, and many more
- “Drive” the car safely with advanced control systems
 - analyze data from different sensors and cameras;
 - plan a path to the desired location.

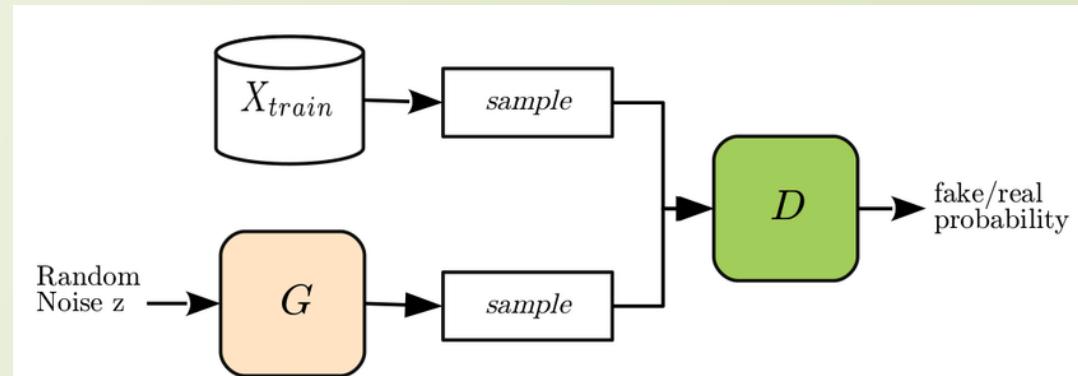
Generative Adversarial Networks (GANS)



Are these images true or fake
("computer generated")?

Game Theory

- Generator (G)
- Discriminator (D)

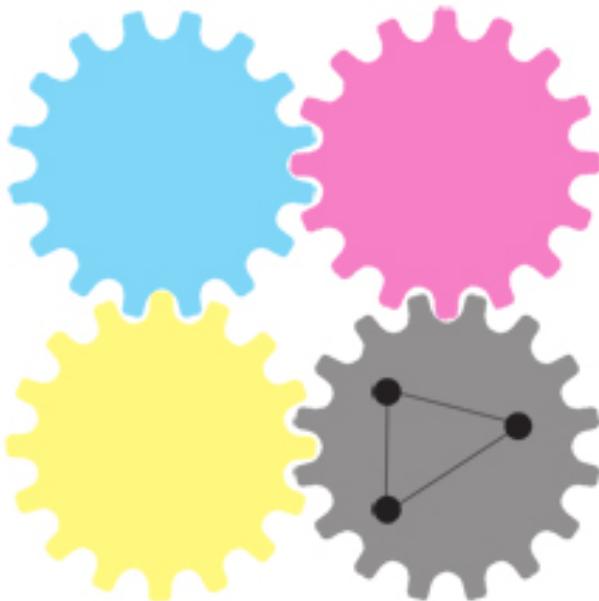


Applications:

- Science (improve astronomical images, simulate physics experiments)
- Art (generate art, fashion models)
- Video games (high resolution images)

Cross-Disciplinary Collaboration

MULTIdisciplinary

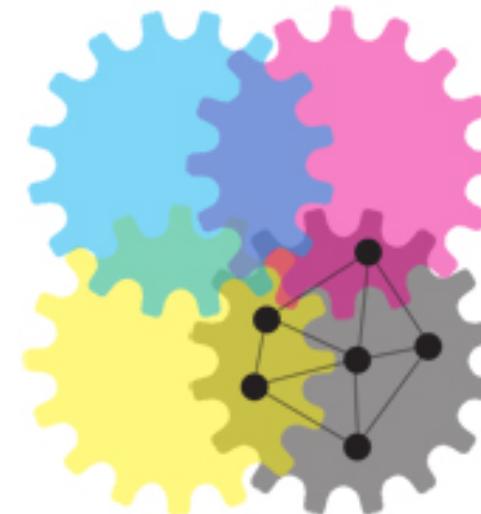


Everyone working on the same problem within silo boundaries of own disciplines under their assumptions and restrictions

Outcomes add to the body of knowledge

Little innovation due to fixed philosophy & work in isolation from other disciplines

INTERdisciplinary



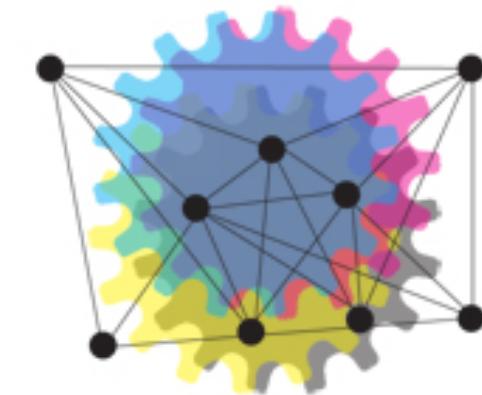
Everyone working on the same problem with overlapping disciplinary boundaries blending of assumptions and restrictions

Outcomes add to the body of knowledge & give theoretical solutions to problems

Some innovation due to flexible philosophy & work influenced by other disciplines

**Cooperation yields disruptive innovation
Collaboration yields cocreative innovation**

TRANSdisciplinary



Everyone working on the same problem by transcending disciplinary boundaries drawing on non-traditional perspectives crossfertilizing assumptions/restrictions resolving contradictory points of view

Outcomes add to the body of knowledge & provide practical solutions to problems

Lot of innovation due to open philosophy & work transformed by other disciplines

Results in improved theories or models, newly invented methods or techniques, novel synergy of systems or structures, and innovative thinking or technologies



Statistical Machine Learning in AI



What is Statistics

Science of Data: A discipline of data collection, organization, analysis, interpretation, and presentation

Data are noisy, random, uncertainty.

Goal: to understand and control the
Source of variation.

Main statistical methods:

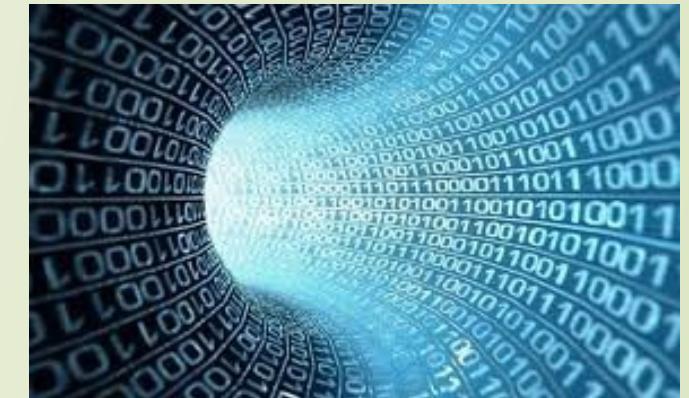
- **descriptive statistics:** summarize and visualize data (e.g. histograms)
 - **inferential statistics:** draw conclusions from random data (e.g. hypothesis test, confidence intervals, linear regression)



Big Data

We are better collecting at data

- scientific measurements, experiments (astronomy, physics, genetics, etc.).
- peer-to-peer communication (images, text)
- broadcasting (News, blogs, videos)
- Social Networking (Facebook, Twitter)
- Authorship (digital books, magazines, html)
- Administrative (enterprise, government, legal)
- Business (e-commerce, stock, advertising)



Bytes=8 bits

Kilobyte (KB) = 10^3 bytes

Megabyte (MB) = 10^6 bytes

Gigabyte (GB) = 10^9 bytes,

Terabyte (TB) = 10^{12} bytes

Petabyte (PB)= 10^{15} bytes

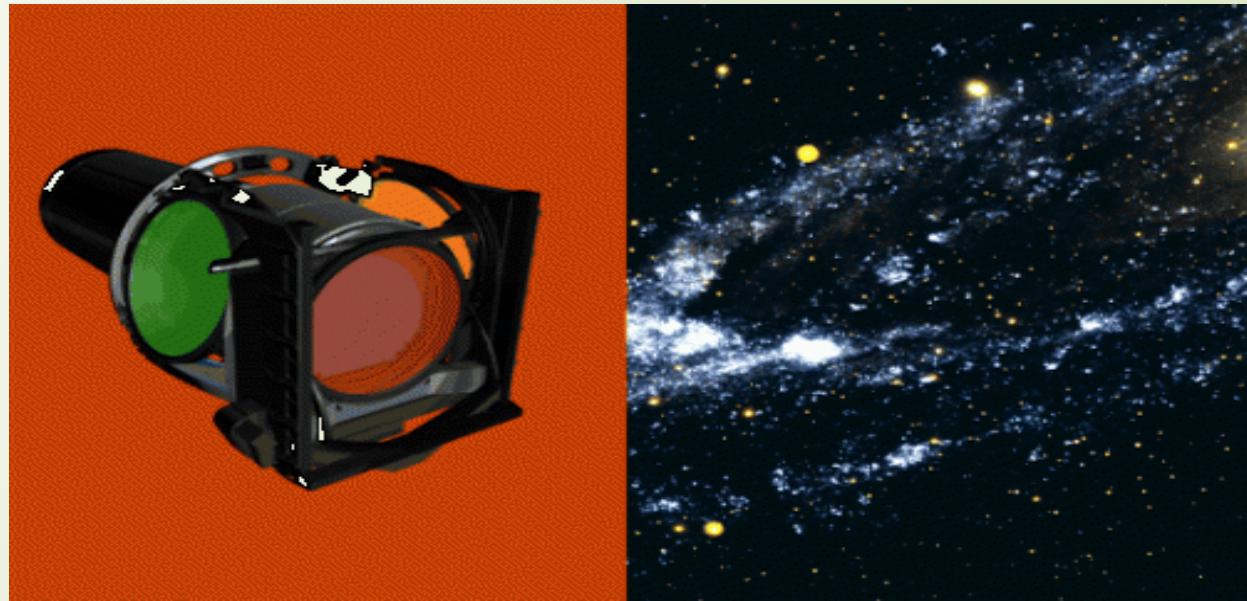
Exabyte (EB)= 10^{18} bytes

Zettabyte (ZB)= 10^{21} bytes

Yottabyte (YB)= 10^{24} bytes

Large Synoptic Survey Telescope (LSST)

- the deepest and widest image of the Universe
- the world's most powerful digit camera
(3200 mega-pixel)



map the entire visible sky in a few nights

- 27-ft (8.4-m) mirror
- 10-year survey of the sky
- 15 Terabytes of data ... every night
- **built by UA scientists**



A Blessing or A Curse ?

Bless

- More information
- opportunities to discover more
- AI needs a large amount of data

observations to learn - “teach” or "train" the machines



Challenges: large scale, complexity, high dimensionality

- Computation (storage, retrieval, operation, analysis, speed)
- Method and Theory, “**curse of dimensionality**” – classical statistical methods designed for small data
- Garbage in, Garbage out



Statistical Machine Learning

Combine statistics and computational sciences
(computer science, systems science, optimization) to
find hidden patterns in large amount of data

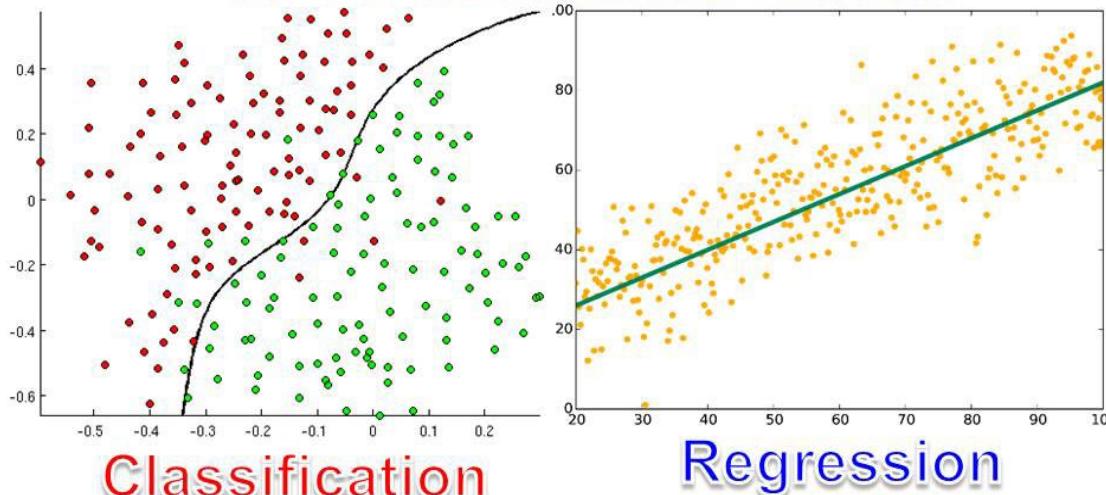
- scalable algorithms
- data-oriented tech and software
- distributed architecture
- advanced statistical methods,
modeling tools, mathematical theory
for data analysis



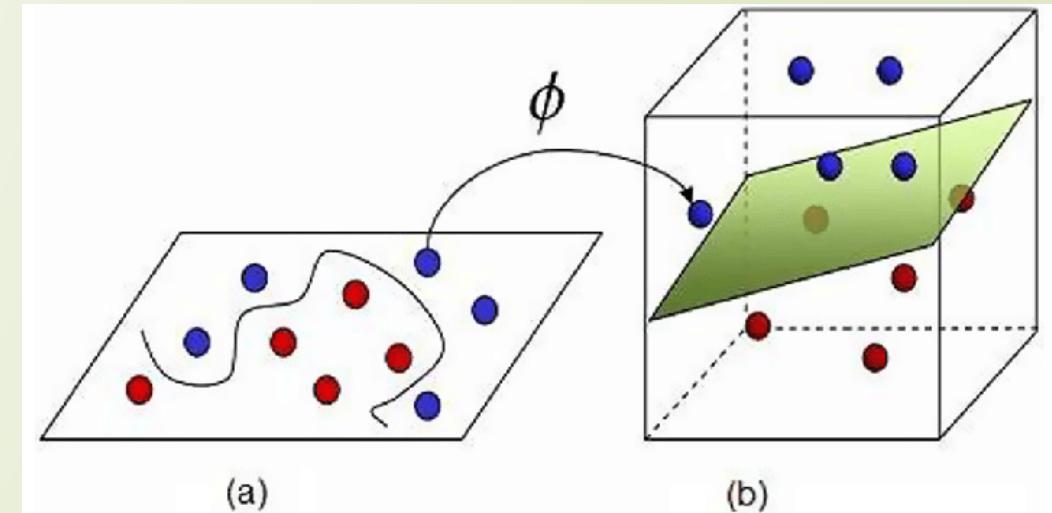


Hidden Patterns in Data

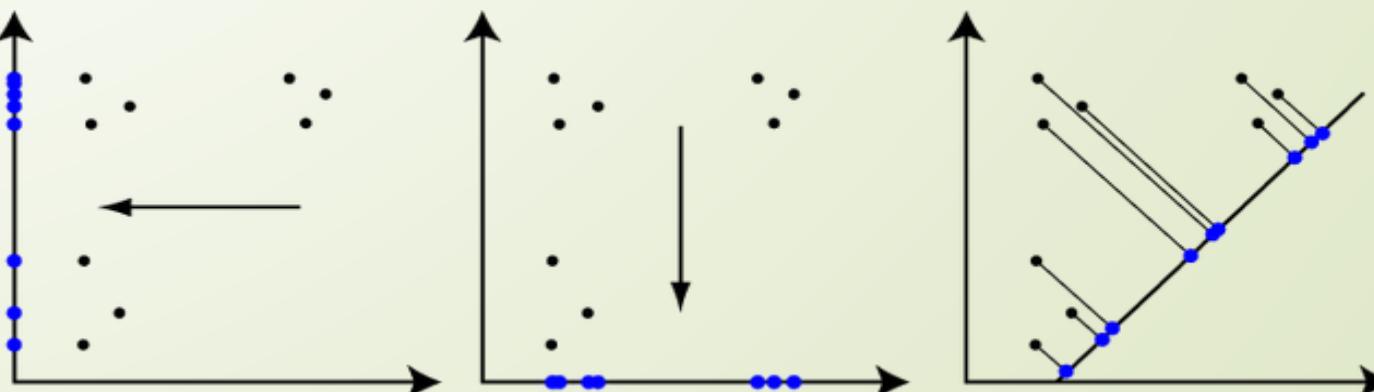
What is the Difference Between



Convert Nonlinear Problems to Linear Problems



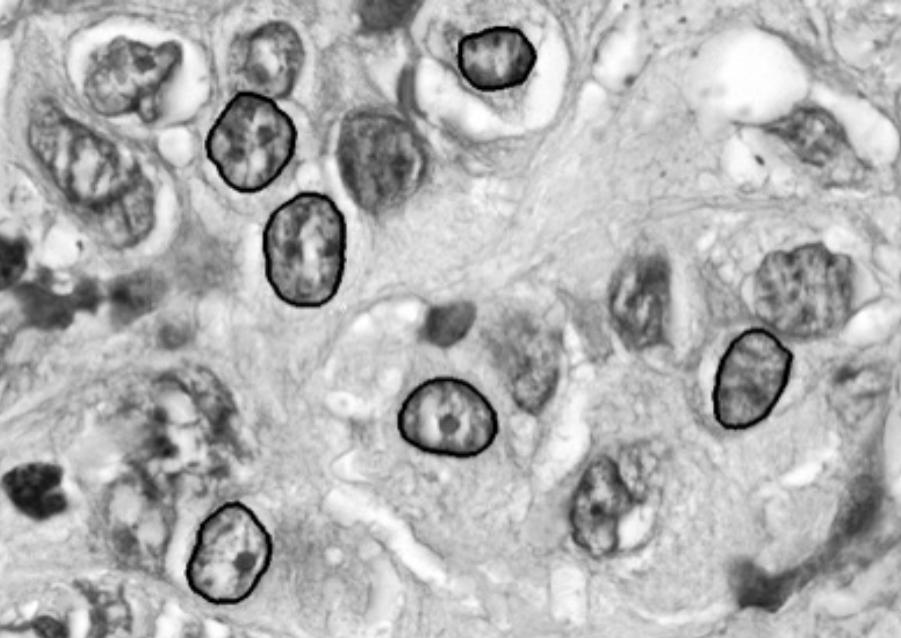
What is the best direction to project data from high-d to low-d



- trend
- relationship
(association, causal)
- dimension reduction

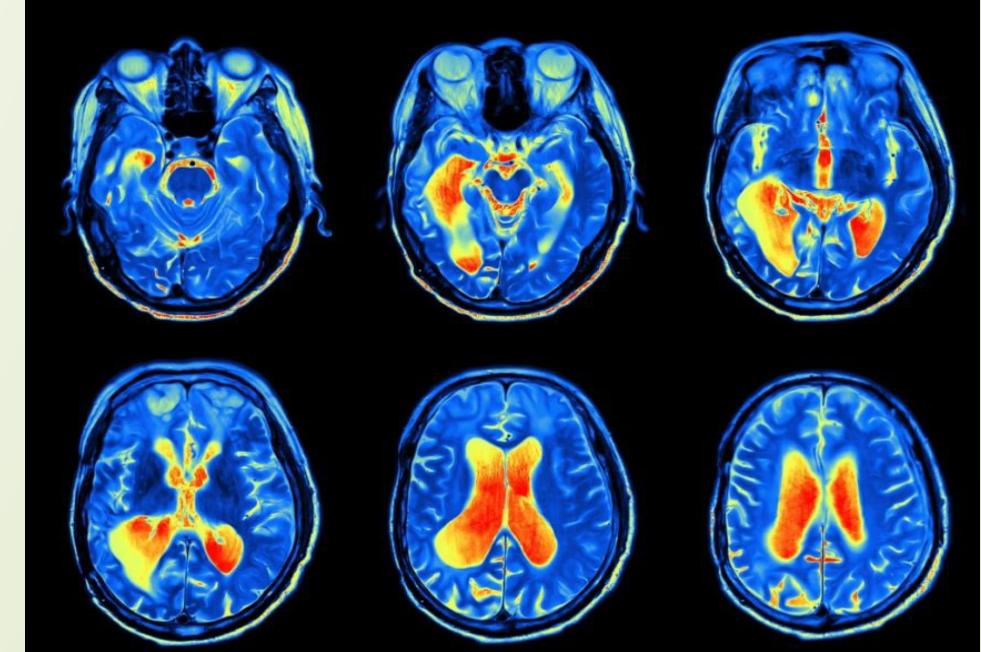


Help Scientists Understand Their Data



Work with biologists and physicians

- fight with cancer
- build automated algorithms to distinguish **cancer cells** vs **normal cells**

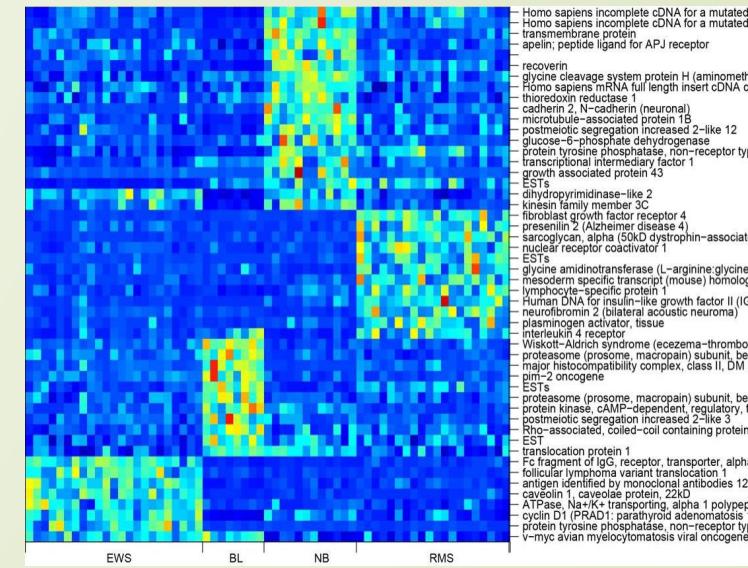
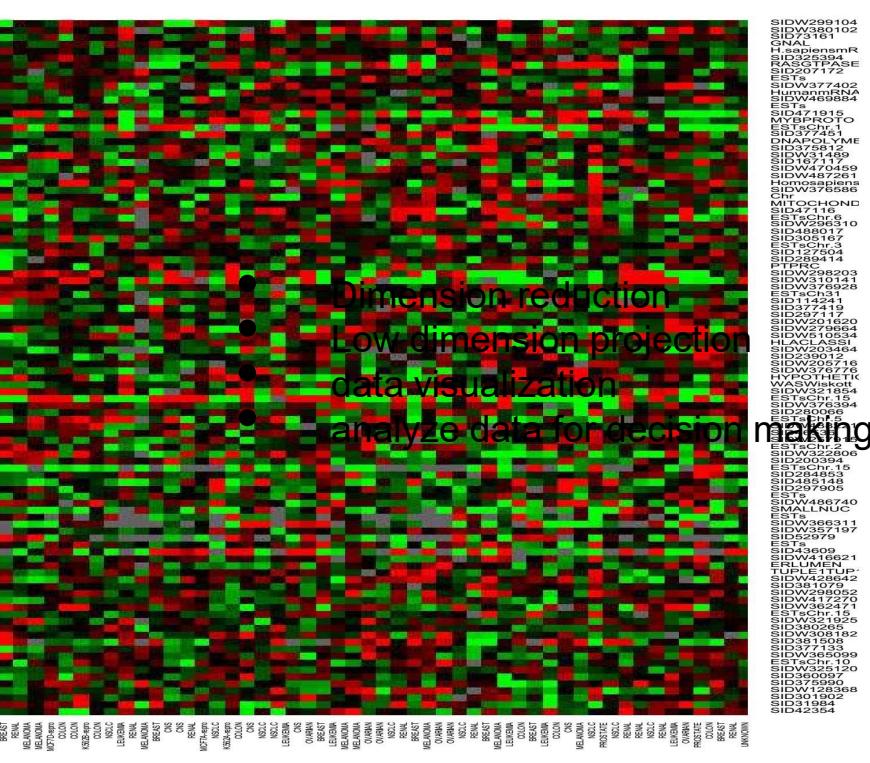


Work with neuroscientists

- understand how the mind works
- which parts of brain control memory, learning, language, attention, problem-solving, decision-making and judgment.



High-dimensional Data Analysis

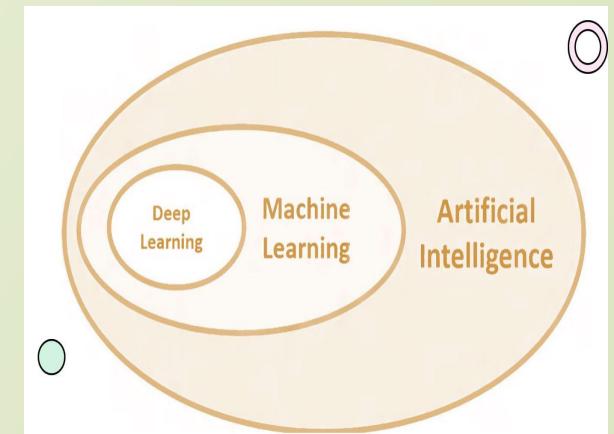


- dimension reduction
 - low dimension projection
 - data visualization
 - reduce noises



Data Science, AI, Machine Learning, Deep Learning

- **Data Science:** all about data. An interdisciplinary field that combines statistical methods, computer science, and domain knowledge to collect, process, analyze, and interpret data in order to extract meaningful insights, make predictions, and support decision-making.
- **AI:** enable machines to understand data, learn from the data, and make decisions (difficult or impossible for humans)
- **Machine learning:** a subset of AI. Statistical and computational tools to find hidden patterns from large amount of data, build models to predict unseen data.
- **Deep learning:** a subfield of ML. Its uses a complex structure of algorithms to create an “artificial neural networks” for learning and Decision making.





Future of AI



AI has the potential to transform every aspect of how we work, play, and live.



Can AI replace humans entirely?



Future of AI



Even the most sophisticated AI can't replace our most quintessentially human capacity

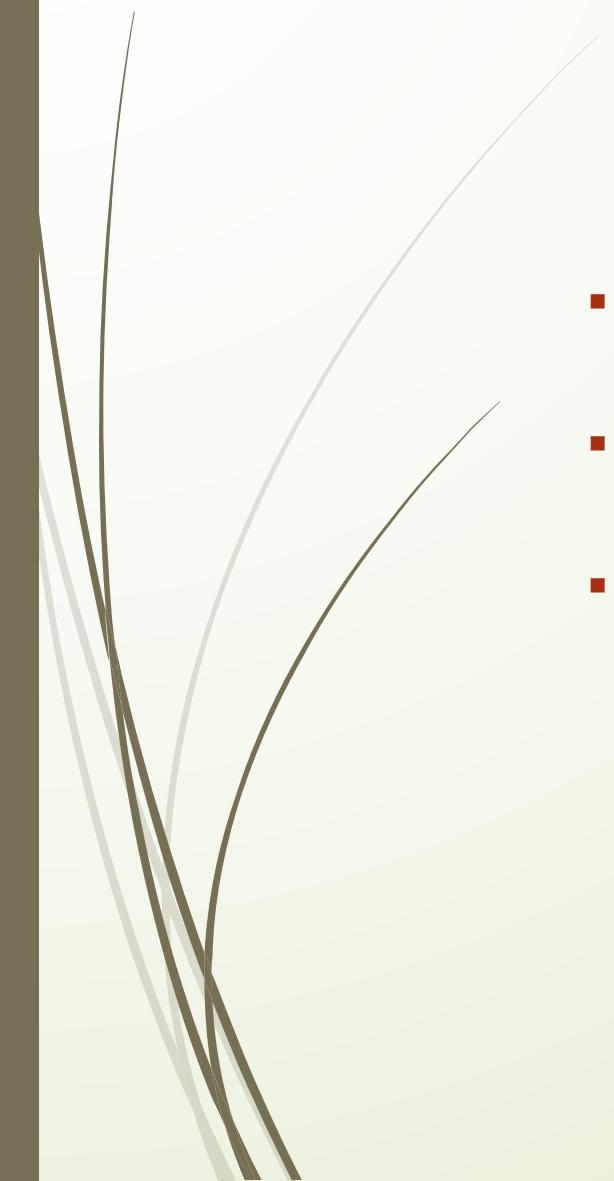
the ability to find inspiration in the world around us and use our innate creativity to make science and art.



Challenges of AI

To understand how natural (real) intelligence works

- **We know** the brain contains billions and billions of neurons, and that we think and learn by establishing electrical connections between different neurons.
- **We don't know** exactly how all of these connections add up to higher reasoning, or even low-level operations. The complex circuitry seems incomprehensible.



Recap

- Artificial Intelligence (AI)
- Opportunities and Challenges
- Statistical Foundations: Statistical Machine Learning