

CS 564: Foundations of ML

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Introduction

Artificial Intelligence

THE MOST EXCITING DISCIPLINE in

Today's World

Artificial Intelligence: Not merely a humanoid robot

- AI, as often portrayed, in science fiction is NOT only robots or other humanoid beings
 - **who are friendly and serve humans or,**
 - **turn evil and want to kill all humans to take control of our planet**

*Fei-Fei Li, Director of Stanford AI lab, claims that the myth of the **terminator** coming next door is, in fact, a real crisis for the development of the AI field as it highlights the public misreading of the technology but also reveals the fear of what are the intentions of the people behind the technology (2018)*

- AI is, in fact, an ever-evolving term which is one of the reasons that it means very different things to different people
- Artificial Intelligence is hard to define because the field has been redefined continuously with the advances of technology and the ambiguity of what we consider as “intelligent”

A better understanding of AI is crucial to its future development and progress

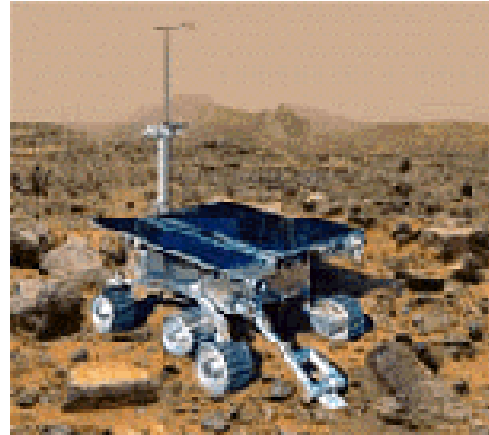
Artificial Intelligence: *Facts & Figures*

- According to Statista, revenue from the artificial intelligence (AI) software market worldwide is expected to reach **126 billion dollars by 2025**
- As per Gartner, 37% of organizations have implemented AI in some form. The percentage of enterprises employing AI grew **270% over the past four years**
- According to Servion Global Solutions, by 2025, **95% of customer interactions will be powered by AI**

Why study AI?



Labor



Science



Search engines



Medicine/
Diagnosis



Appliances

What else?

Natural Language Question Answering



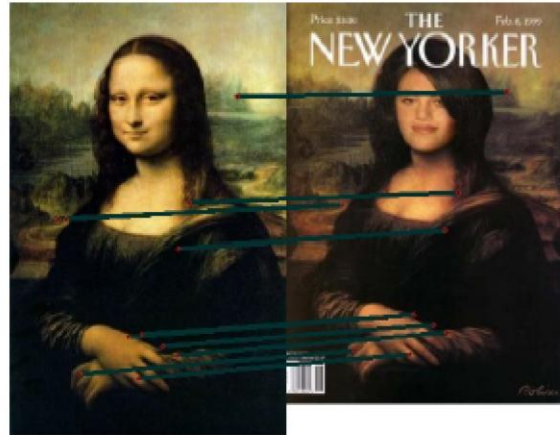
<http://aimovie.warnerbros.com>

<http://www.ai.mit.edu/projects/infolab/>

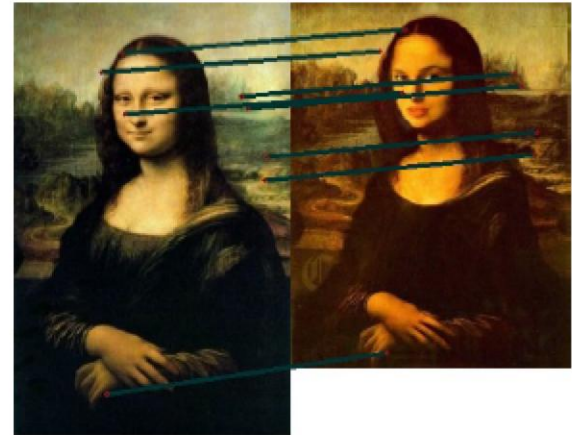
8/28/2025

Examples: AI at Google

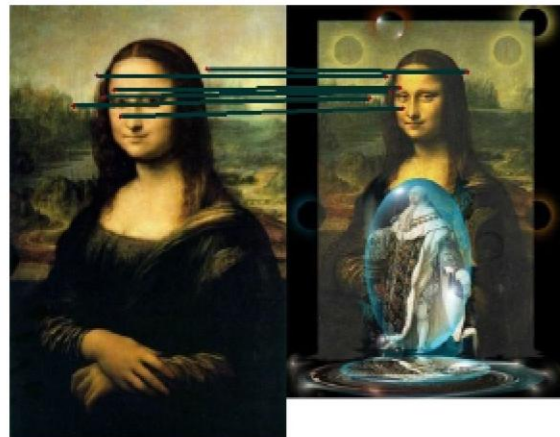
Compare low-level features



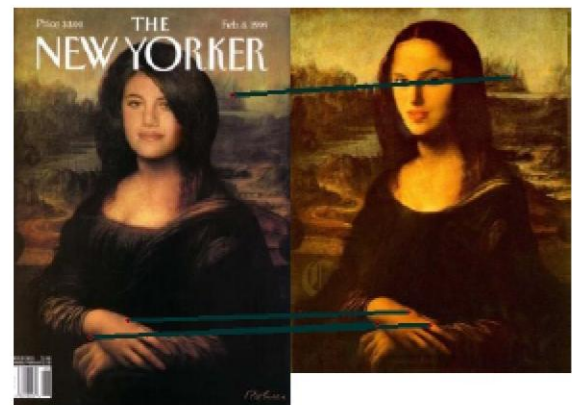
(a) A v.s. B



(b) A v.s. C



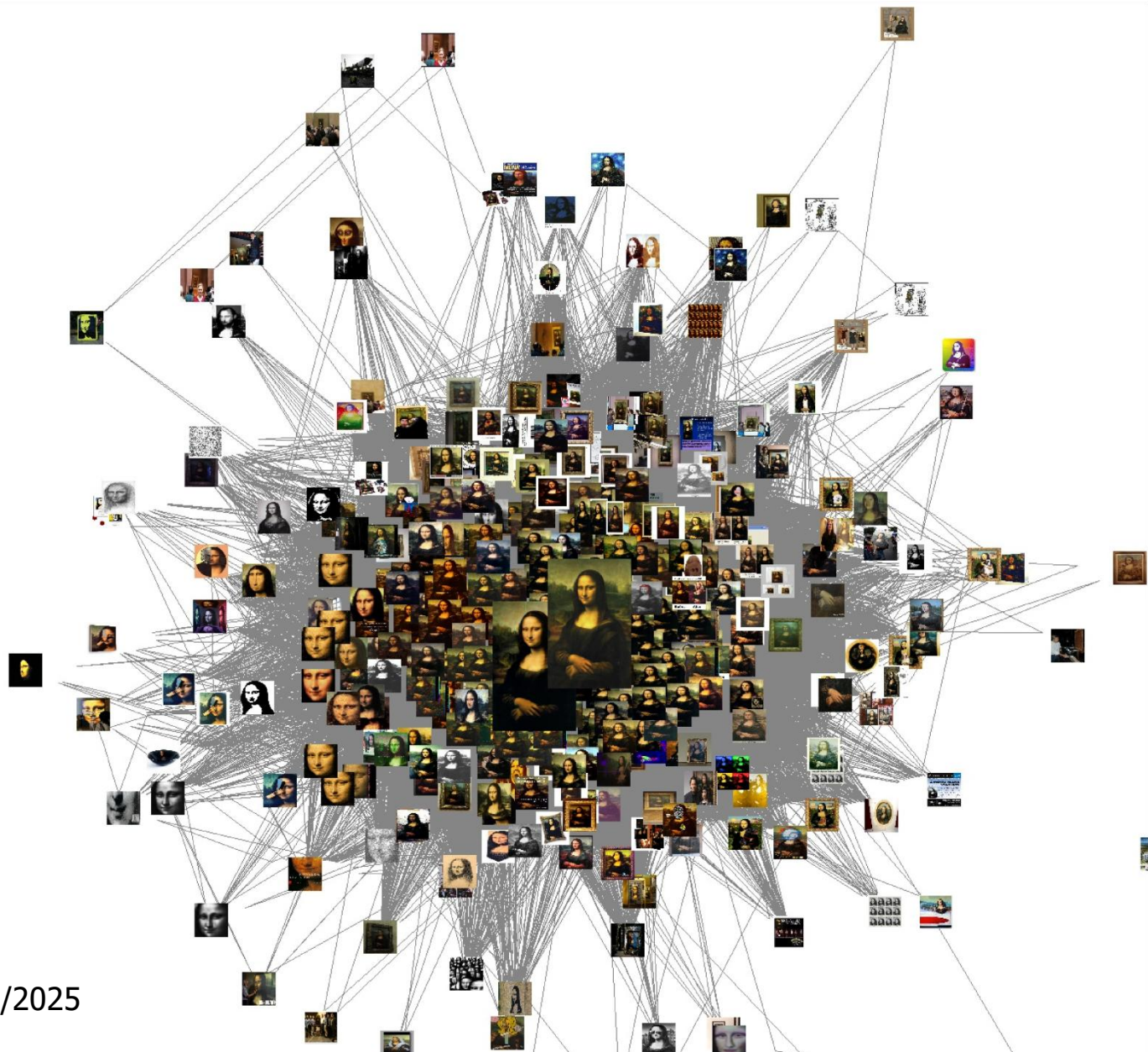
(c) A v.s. D



(d) B v.s. C

8/28/2025

Induced Graph



8/28/2025

Route Finding

2. Turn left

210 m

3. At the roundabout, take the 2nd exit onto IIT Main Rd

250 m

Take NH922 to Anisabad Post Office Rd/Dhira Chak Main Rd/Khagaul Rd/Mithapur - Anisabad - Khagaul Rd in Anisabad, Patna

53 min (28.8 km)

4. Turn left at Singh Da Dhaba onto Bihta Kanpa Rd

Pass by SURAJ Hotel (on the right in 450 m)

1.4 km

5. At Pradip Communication, continue onto Bihta Rd/Bikram - Bihta Rd

Continue to follow Bikram - Bihta Rd

Pass by Hanuman Mandir (on the left)

2.3 km

Take IIT Main Rd to Bihta Kanpa Rd

2 min (550 m)

1. Head northeast

Pass by SBI ATM (on the left)

88 m

2. Turn left

210 m

3. At the roundabout, take the 2nd exit onto IIT Main Rd

250 m

Take NH922 to Anisabad Post Office Rd/Dhira Chak Main Rd/Khagaul Rd/Mithapur - Anisabad - Khagaul Rd in Anisabad, Patna

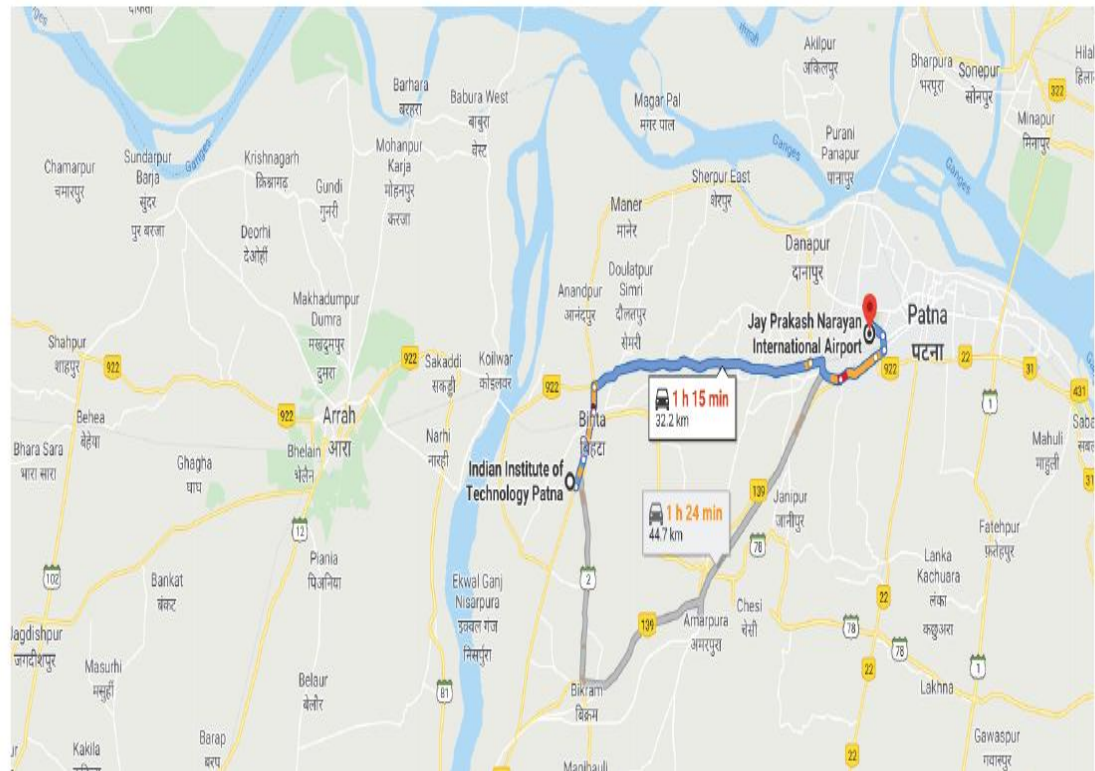
8/24/2020

Indian Institute of Technology Patna to Jay Prakash Narayan International Airport - Google Maps

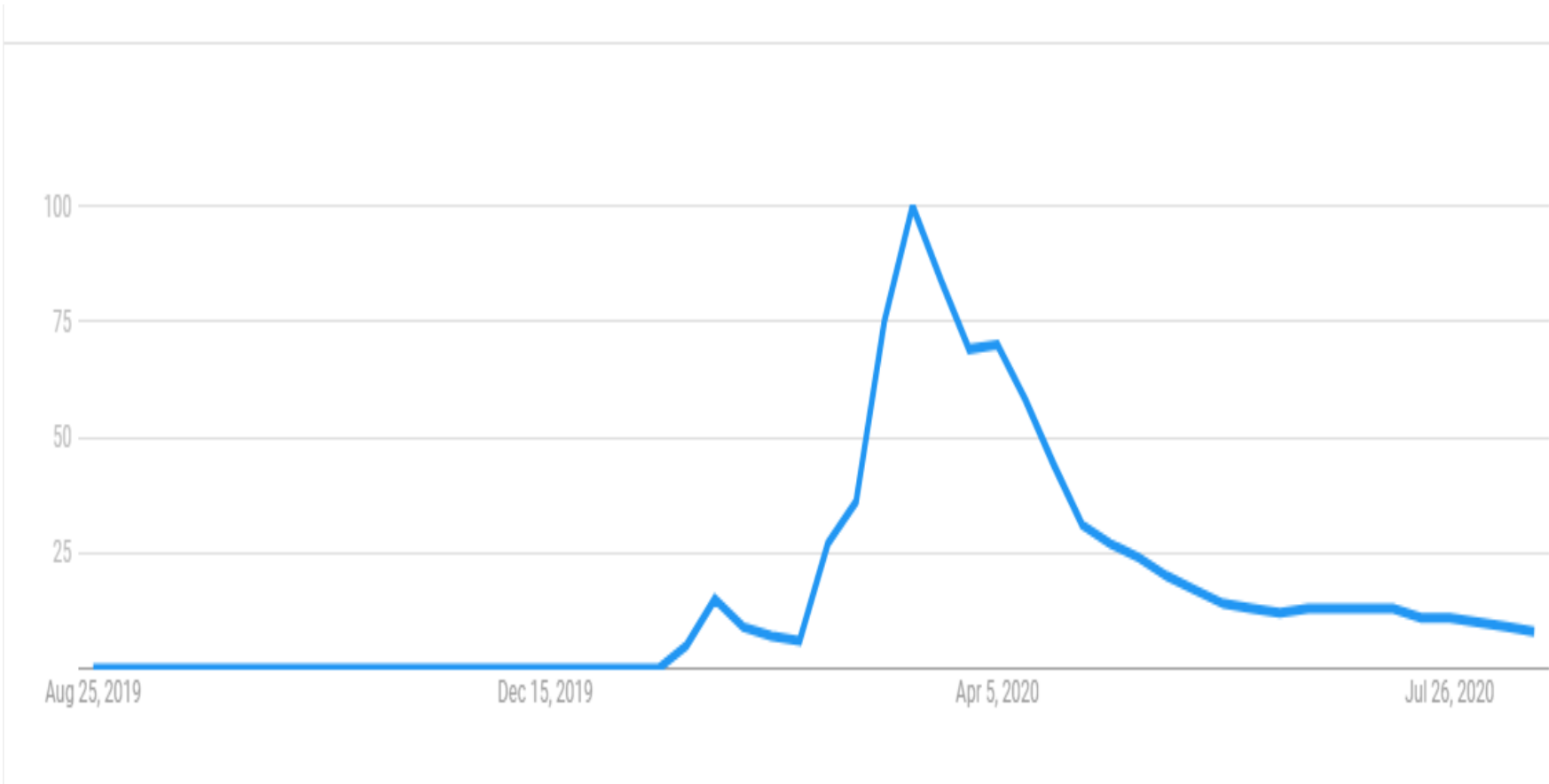


Indian Institute of Technology Patna to Jay Prakash Narayan International Airport

Drive 32.2 km, 1 h 15 min



COVID-19 Trend



Making sense of data



<http://youtu.be/kb7RL6b-mHE>

Defining Data

- **Data**-A collection of raw, unorganized plain facts, observations, statistics, characters, symbols, images, numbers
- **Ex:**
10, 25, ..., Jodhpur, 10CS3002, asif@iitj.ac.in
Anything else?

Customer surveys, paper and electronic forms, CVs, and so on

- **Information** = Data + Meaning

When data is processed, evaluated, organized, structured, or presented in such a way that it becomes meaningful or helpful

Ex: avg score of a class

Big Data

Now data is Big Data!

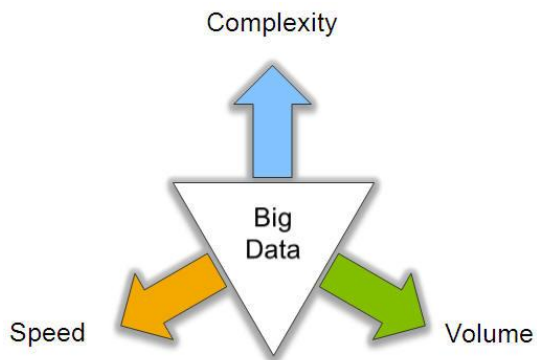
- No single standard definition!
- 'Big-data' is similar to 'Small-data', but bigger
...but having data bigger consequently requires different approaches
 - techniques, tools and architectures

...to solve: new problems

...and, of course, in a better way

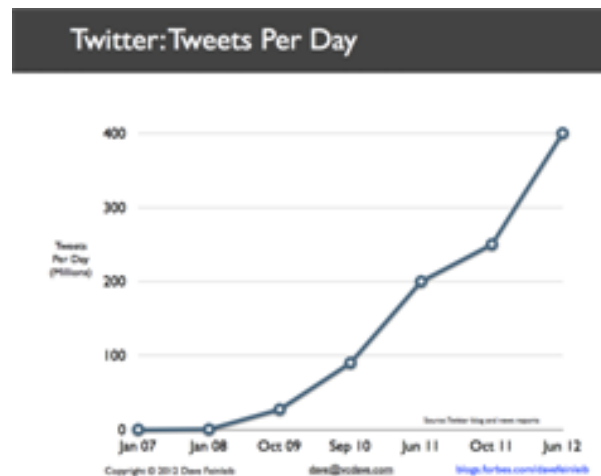
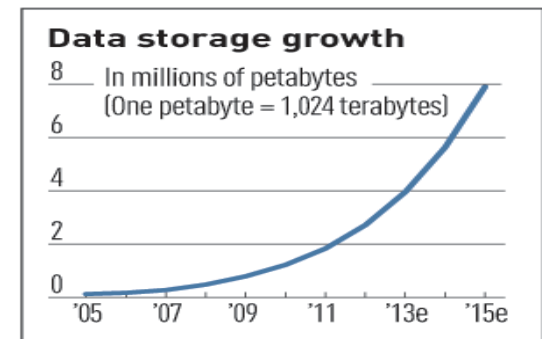
Big data is data whose scale, diversity, and complexity require new architecture, techniques, algorithms, and **analytics** to manage it and extract value and hidden knowledge from it...

Characteristics of Big Data: V3



V3 : V for Volume

- Volume of data, which needs to be processed is increasing rapidly
 - More storage capacity
 - More computation
 - More tools and techniques

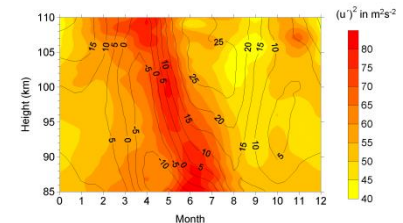
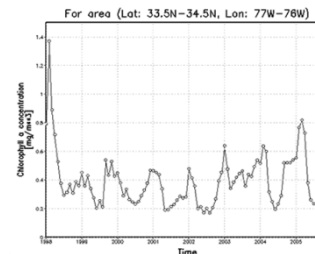
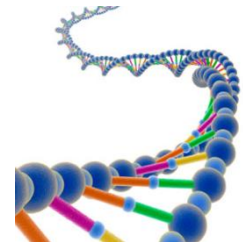
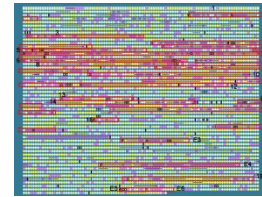


*Exponential increase in
collected/generated data*

V3: V for Variety

- Various formats, types, and structures
 - Text, numerical, images, audio, video, sequences, time series, social media data, multi-dimensional arrays, etc...
- Static data vs. streaming data
- A single application can be generating/collecting many types of data

To extract knowledge → all these types of data need to be linked together



V3: V for Velocity

- Data is being generated fast and need to be processed fast
 - For time-sensitive processes such as catching fraud, big data must be used as it streams into your enterprise in order to maximize its value
 - Scrutinize 5 million trade events created each day to identify potential fraud
 - Analyze 500 million daily call detail records in real-time to predict customer churn faster



Big data: Blessing or curse?

Information is the main treasure of humankind

Without efficient management, such a treasure becomes useless:
the more we have, the less we can use!

Web is Enormous

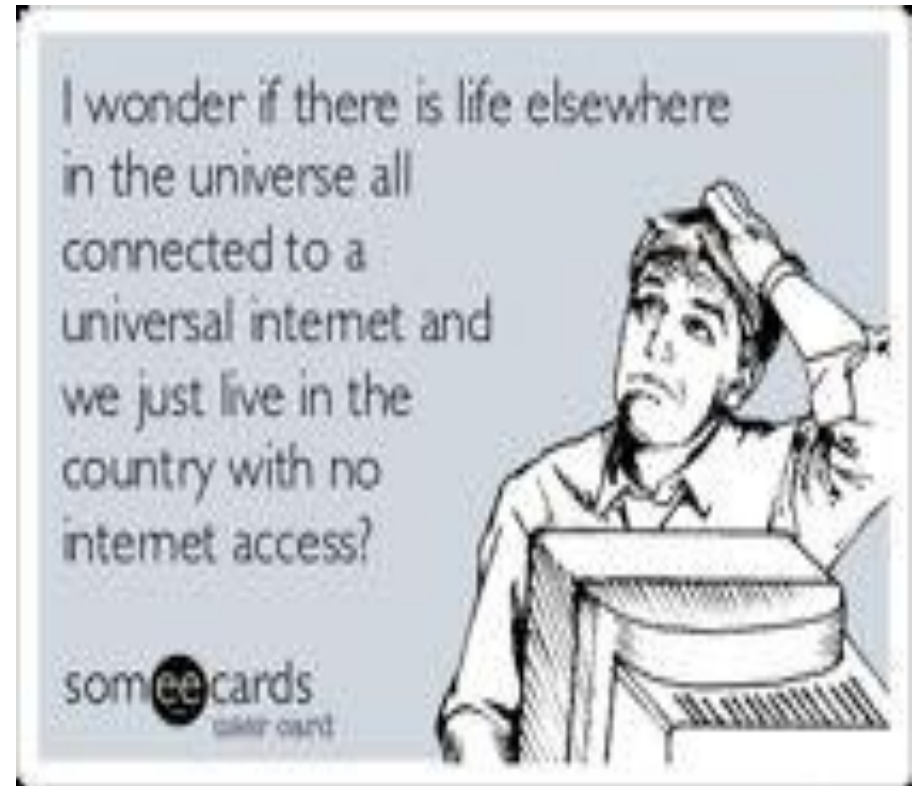
Web: connecting people

- The potential for Knowledge sharing today is unmatched in history
- Never before have so many knowledgeable people been connected

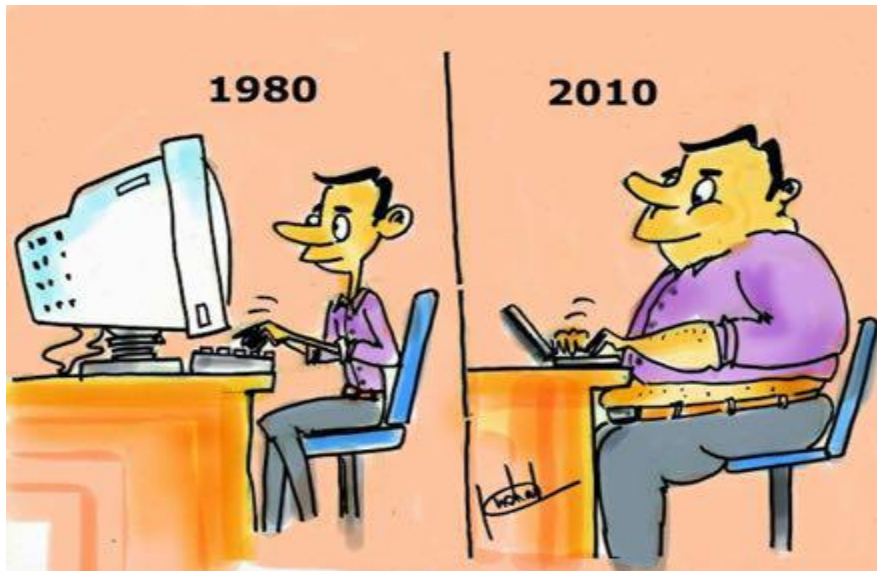


To be or not to be connected?

***Being connected is good
but being disconnected for
the past millions years was
the main reason behind our
cultural diversity***



Being disconnected!



Artificial Intelligence: *Application*

All-inclusive Digital India

- 635 million internet users
- **Multilingual information access** to the low-income citizens is very important
- Differently abled and visually challenged people should be part of this digital revolution

Artificial Intelligence: *Application*

■ **AI in Life Styles**

- Autonomous Vehicles
- Spam Filters
- Facial Recognition
- Recommendation System

■ **AI in Navigation**

- GPS technology can provide users with accurate, timely, and detailed information to improve safety

Artificial Intelligence: *Application*

■ **AI in E-commerce**

- Personalized Shopping
- AI powered Assistants
- Fraud Prevention

■ **AI in Education**

- Automated Administrative tasks
- Personalized learning
- Automated question and assignment generation
- Help in evaluation
- Creating smart contents
- Voice Assistants

Artificial Intelligence: *Application*

■ **AI in Robotics**

- Carrying goods in hospitals, factories, and warehouses
- Cleaning offices and large equipment
- Inventory management

■ **AI in Human Resources**

- AI and ML to hire right people for a specific position
- Scanning of profiles and resumes

Artificial Intelligence: *Application*

■ **AI in Healthcare**

- **Bot** to assist patients with the queries of their symptoms, access the health records, medicines to take, information about the hospitals, precautions to be taken etc.
- **Multilingual report generation** from clinical records and radiology examinations
- Useful **information extraction** from clinical records
- Detecting diseases and identify cancer cells

■ **AI in Agriculture**

- Backbone of India
- Identify defects and nutrient deficiencies in the soil
- **Multilingual Chatbot** for the farmers
- Could provide information on crops, soil condition, weather condition, fertilizers, pesticides, market condition, price etc

Artificial Intelligence: *Application*

■ **AI in Gaming**

- Creating smart, human-like NPCs to interact with the players
- Predicting human behaviors through game design

■ **AI in Automobiles**

- To build self-driving vehicles
- Improve in-vehicle experience
- Provide additional supports like emergency braking, blind-spot monitoring and driver-assist steering

Artificial Intelligence: *Application*

■ **AI in Social Media**

- Instagram
- Facebook
- Twitter

■ **AI in Marketing**

- Using AI, marketers can deliver highly targeted and personalized ads with the help of behavioral analysis, pattern recognition, etc.
- AI can help with content marketing in a way that matches the brand's style and voice
- Chatbots to interact with the users

Artificial Intelligence: *Application*

■ **AI in Finance**

- AI can help to significantly improve a wide range of financial services
- Customers looking for wealth management solutions can get information through SMS, Online Chat etc
- Fraud detection
- Detecting transaction patterns

AI is Real Fun!

What is AI?

<p>“The exciting new effort to make computers think ... <i>machines with minds</i>, in the full and literal sense” (Haugeland, 1985)</p> <p>“[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning ...” (Bellman, 1978)</p>	<p>“The study of mental faculties through the use of computational models” (Charniak and McDermott, 1985)</p> <p>“The study of the computations that make it possible to perceive, reason, and act” (Winston, 1992)</p>				
<p>“The art of creating machines that perform functions that require intelligence when performed by people” (Kurzweil, 1990)</p> <p>“The study of how to make computers do things at which, at the moment, people are better” (Rich and Knight, 1991)</p>	<p>“A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes” (Schalkoff, 1990)</p> <p>“The branch of computer science that is concerned with the automation of intelligent behavior” (Luger and Stubblefield, 1993)</p>				
<p>Figure 1.1 Some definitions of AI. They are organized into four categories:</p> <table><tr><td>Systems that think like humans.</td><td>Systems that think rationally.</td></tr><tr><td>Systems that act like humans.</td><td>Systems that act rationally.</td></tr></table>		Systems that think like humans.	Systems that think rationally.	Systems that act like humans.	Systems that act rationally.
Systems that think like humans.	Systems that think rationally.				
Systems that act like humans.	Systems that act rationally.				

From Wikipedia

Artificial intelligence (AI) is the [intelligence](#) of machines and the branch of [computer science](#) that aims to create it. Textbooks define the field as "the study and design of [intelligent agents](#)"^[1] where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success.^[2] [John McCarthy](#), who coined the term in 1956,^[3] defines it as "the science and engineering of making intelligent machines."^[4]

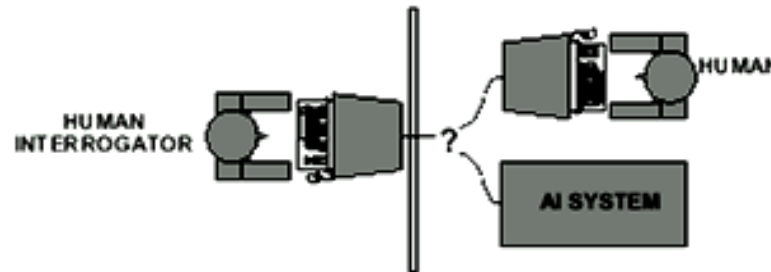
The field was founded on the claim that a central property of humans, intelligence—the [sapience](#) of *[Homo sapiens](#)*—can be so precisely described that it can be simulated by a machine.^[5] This raises philosophical issues about the nature of the [mind](#) and limits of scientific [hubris](#), issues which have been addressed by [myth](#), [fiction](#) and [philosophy](#) since antiquity.^[6] Artificial intelligence has been the subject of optimism,^[7] but has also suffered setbacks^[8] and, today, has become an essential part of the technology industry, providing the heavy lifting for many of the most difficult problems in computer science.^[9]

AI research is highly technical and specialized, deeply divided into subfields that often fail to communicate with each other.^[10] Subfields have grown up around particular institutions, the work of individual researchers, the solution of specific problems, longstanding differences of opinion about how AI should be done and the application of widely differing tools. The central problems of AI include such traits as reasoning, knowledge, planning, learning, communication, perception and the ability to move and manipulate objects.^[11]

General intelligence (or "[strong AI](#)") is still a long-term goal of (some) research.^[12]

Acting Humanly: The Full Turing Test

- Alan Turing's 1950 article *Computing Machinery and Intelligence* discussed conditions for considering a machine to be intelligent
 - “Can machines think?” \longleftrightarrow “Can machines behave intelligently?”
 - The Turing test (The Imitation Game): Operational definition of intelligence

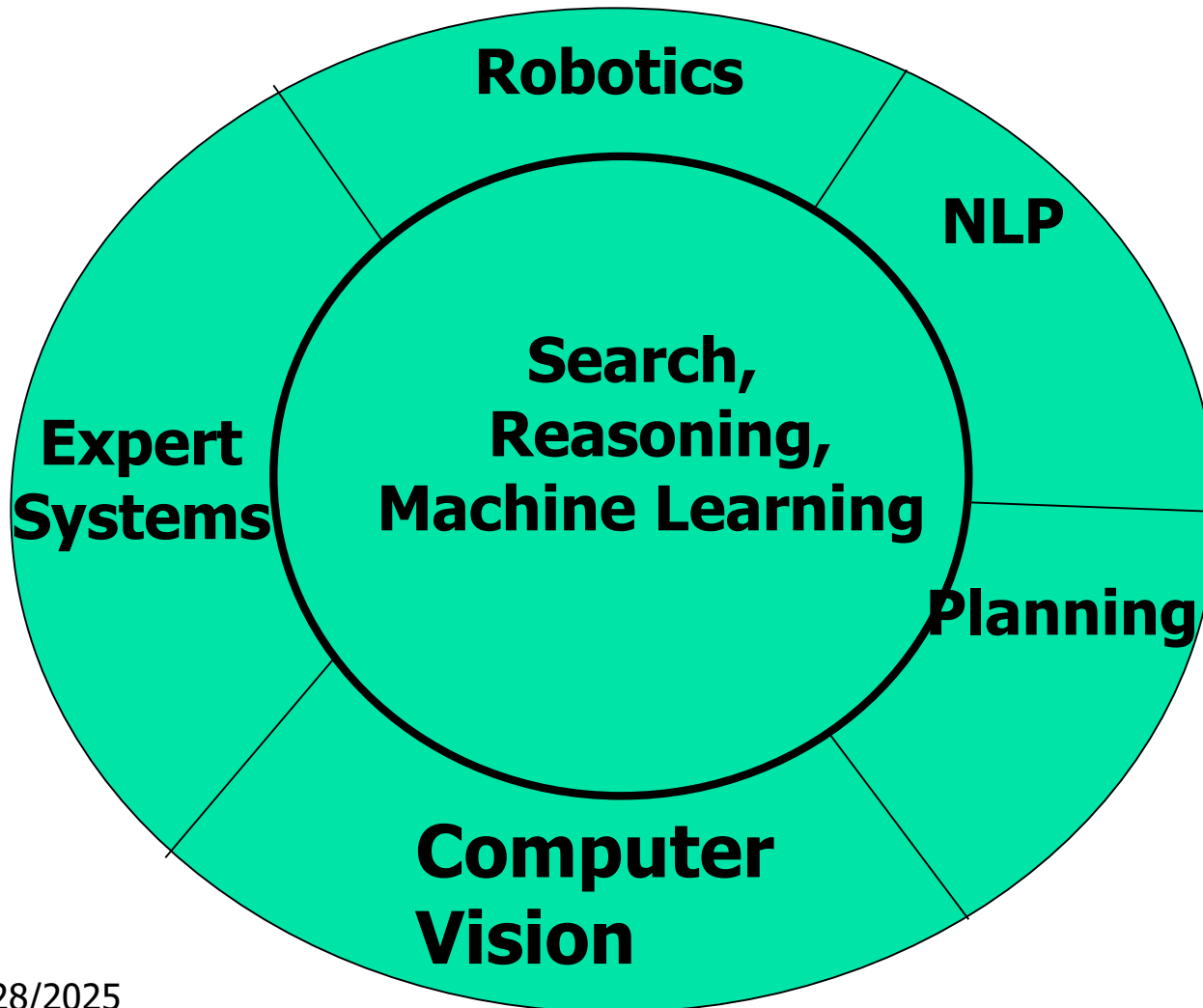


- Computer needs to possess: Natural language processing, Knowledge representation, Automated reasoning, and Machine learning
- Problem: 1) Turing test is not reproducible, constructive, and amenable to mathematic analysis. 2) What about physical interaction with interrogator and environment?
- Total Turing Test: Requires physical interaction and needs perception and actuation.

What would a computer need to pass the Turing test?

- **Natural language processing:** to communicate with examiner
- **Knowledge representation:** to store and retrieve information provided before or during interrogation
- **Automated reasoning:** to use the stored information to answer questions and to draw new conclusions
- **Machine learning:** to adapt to new circumstances and to detect and extrapolate patterns
- **Vision :** to recognize the examiner' s actions and various objects presented by the examiner
- **Motor control:** to act upon objects as requested
- **Other senses:** such as audition, smell, touch, etc.

Disciplines which form the core of AI- inner circle
Fields which draw from these disciplines- outer circle



Allied Disciplines

Philosophy	Knowledge Rep., Logic, Foundation of AI (is AI possible?)
Maths	Search, Analysis of search algos, logic
Economics	Expert Systems, Decision Theory, Principles of Rational Behavior
Psychology	Behavioristic insights into AI programs
Brain Science	Learning, cognitive science, Neural Nets
Physics	Learning, Information Theory & AI, Entropy, Robotics
Computer Sc. & Engg.	Systems for AI

AI State-of-the-art

- Google's powerful search engines, Google's MT
- Alexa etc.
- Amazon Comprehend Medical services
- Social Networks: Facebook, Twitter etc

- **ChatGPT**

- **GPT-4**

Machine Learning

- **Machine learning**: how to acquire a model on the basis of data / experience?
 - Learning parameters (e.g. probabilities)
 - Learning structure (e.g. BN graphs)
 - Learning hidden concepts (e.g. clustering)

Machine Learning

- Unsupervised Learning
 - No feedback from teacher; detect patterns
- Reinforcement Learning
 - Feedback consists of rewards/punishment
- Supervised Learning
 - Examples of correct answers are given
 - Discrete answers: *Classification*
 - Continuous answers: *Regression*

AI & ML: From Past to Present

■ Classical ML algorithms

- Used extensively (Rule-based, Naïve Bayes, HMM, MaxEnt, CRF, SVM, Logistic Regression etc.)
- Requires handcrafting of features
- Time-consuming
- Curse of dimensionality

■ Deep Learning algorithms

- No feature engineering
- Success of distributed representations (especially for Natural Language Processing System)

Top-10 Classical ML/Deep Learning algorithms : ICDM-2006

- C4.5 (Decision Tree)
- k-Means
- SVM
- Apriori
- EM
- PageRank
- AdaBoost
- kNN
- **Naive Bayes**
- CART

Top 10 data mining algorithms. Knowl Inf Syst (2008) 14:1–37 DOI 10.1007/s10115-007-0114-2

AI & ML: From Past to Present

- **Some recent developments in Deep Learning**
 - The rise of distributed representations (e.g., Word2vec, GLOVE, ELMO, BERT etc)
 - Convolutional, recurrent, recursive neural networks, Transformer, Reinforcement learning
 - Unsupervised sentence representation learning
 - Combining deep learning models with memory-augmenting strategies
- Explainable AI

AI: Future

- Artificial General Intelligence :
able to exhibit human intelligence
- Artificial Super Intelligence :
surpasses human intelligence in many aspects

from creativity to general wisdom to problem-solving —
will require machines to experience consciousness

Recognition for Modern AI

*Yoshua Bengio, Geoffrey Hinton, and Yann LeCun
received the*

*Turing Award-2018 (equivalent to Nobel Prize of
Computing)*

- *for Modern AI (specifically for deep learning
research)*

Bengio- University of Montreal

Hinton- University of Toronoto & Google

LeCun- Facebook's chief AI scientist and a professor at
NYU

Goal of Teaching the course

- **Concept building**: firm grip on foundations, clear ideas
- **Coverage**: grasp of good amount of material, advances
- **Inspiration**: get the spirit of ML, motivation to take up further work

Course Contents

Fractal I: Supervised Learning

- Introduction to AI and ML; Different Paradigms of Machine Learning
- Bayesian Classification, Decision Tree Learning
- Ensemble methods: Bagging, Boosting, Stacking

Fractal II: Graphical Models, Neural Networks and Deep Learning

- **Introduction to Graphical Models-** HMM, MaxEnt and CRF
- **Neural Network-** Perceptron, Backpropagation
- **Deep Learning-** Recurrent Neural Network, LSTM, GRU, Encoder-Decoder, Attention, Autoencoder, GAN

Fractal-III: Unsupervised Learning and Feature selection

- **Feature Selection and Dimensionality Reduction:** PCA, LDA, Evolutionary algorithm for feature selection
- **Clustering:** k-means clustering, k-medoid, EM-algorithm, agglomerative clustering
- Hypothesis Evaluation, VC-dimension, Bias-variance Tradeoff, Regression

Recent Trends (Theory and Application)

Evaluation

Minor- 25%

Major- 45%

Assignments- 30%

Resources

- T. Mitchell. Machine Learning. McGraw-Hill, 1997.
- Christopher Bishop. Pattern recognition and machine learning. Springer Verlag, 2006.
- Hastie, Tibshirani, Friedman. The elements of Statistical Learning Springer Verlag.
- Probability, Random Variables and Stochastic processes by Papoulis and Pillai, 4th Edition, Tata McGraw Hill Edition.
- A. K. Jain and R. C. Dubes. Algorithms for Clustering Data. Prentice Hall, 198815.

Thank you for your attention!