Great Learning
POWER AHEAD

# Welcome! We will begin shortly

## Beyond the Numbers

**Discovering the fascinating history of data science**

### Learning Outcomes

- Comprehend what data science and analytics means
- Understand the idea of data-driven decision making
- Illustrate how data science has evolved over the past century
- Identify the difference approaches within data science

**Guidelines**

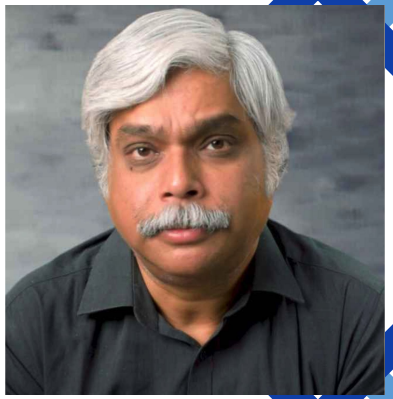
Listen only mode

Ask questions at the interest of the larger audience


Questions in the Q&A Box

**Thank you**

# Meet Your Speaker



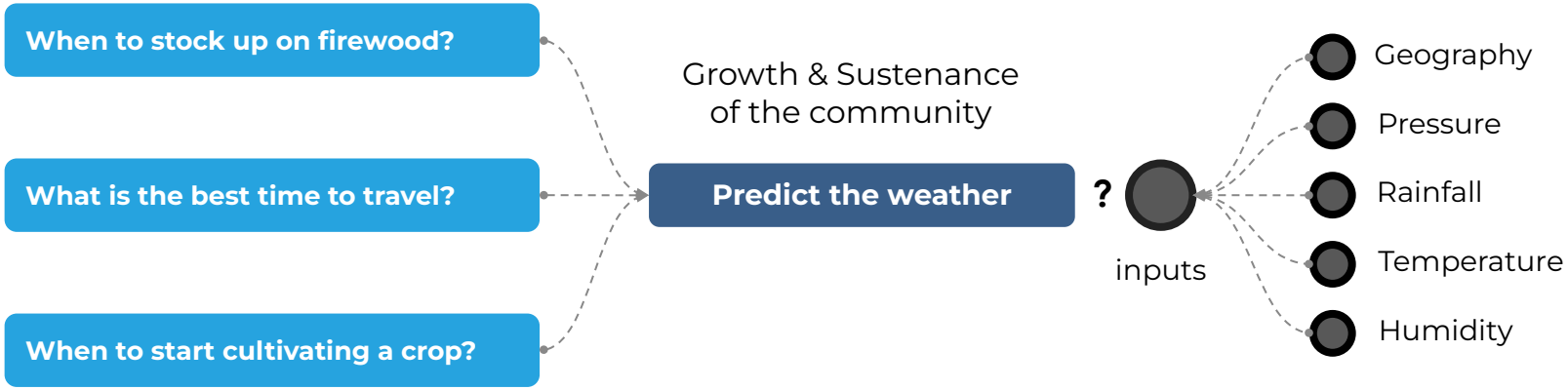
**Dr. Abhinanda Sarkar**
**Academic Director at Great Learning**

- Alumnus - Indian Statistical Institute, Stanford University
- Faculty - MIT, Indian Institute of Management, Indian Institute of Science
- Experienced in applying probabilistic models, statistical analysis and machine learning to diverse areas
- Certified Master Black Belt in Lean Six Sigma and Design for Six Sigma in GE

# Origin of Decisions

Decisions were always **data-driven**

Let's consider few situations that early civilizations might have faced




Decisions are made today by businesses the same way - but the methods have become more **accurate** and **faster** owing to the evolution of **statistical techniques** & **computing capabilities**

# Paradigms in data science

| | Inferential | Computational |
|---|---|---|
| Focus | Make predictions on population based on sample data | Leverage computational methods and technology to scale insight generation |
| Methods | Use statistical methods to draw conclusions / infer from data | Implement algorithms and computational methods to analyse data |
| Limitations | Representativeness of data | Complexity of algorithms and cost of training large models |
| Examples | 1. Effectiveness of a new medication through randomized trial<br>2. Impact of a new policy on citizens | 1. Weather forecasting based on historical and weather patterns<br>2. Optimize routing of vehicles to minimize costs |

# Evolution of Data Science (Early Stats & Computing)

# Evolution of Data Science

**Inferential**

Central Tendency

Expected Values

Probability Theory

< 1940s | 1940s - 50s | 1960s - 70s | 1980s - 90s | 2000s - 10s | 2020+

Telegraph

Difference Engine

Audio Tapes

**Computational**

# Evolution of Data Science (1940s to 1950s)

## Bayesian Statistics

*Use prior knowledge to predict future uncertainties*

- Control Chart Theory - Dr. Walter @ Bell Labs
- Telephone manufacturing - Quality Control Process
- Led to economic benefits - high quality with efficiency
- Lower wastage + Higher product quality

## Digital Computers

*Electronic device which can do math and logical calculations*

- Electronic Numerical Integrator & Computer (ENIAC)
- Developed in US - World War II - Artillery Firing Tables
- Finding trajectories for different types of guns
- Type of ammo + external conditions (temp & wind)

## Sampling Theory

*Make inferences about a population, using a sample*

- Frederick Taylor - Father of Scientific Management
- Manpower Productivity Assessments
- To improve manufacturing processes + efficiency
- Now - advertising by Google/Meta - target audiences

## Monte Carlo Methods

*Run simulations with random inputs to arrive at conclusions*

- Origin - Monte Carlo Casino - chance based games
- Developed during the Manhattan Project - 1940s
- Simulate behavior of neutrons in nuclear reactor
- Now - Predict weather patterns, financial markets

## ANOVA

*Compare the means of 3+ groups - Evidence of difference*

- Ronald A Fisher - statistician & geneticist
- Analyze experiments in Agriculture
- Effect of different fertilizers >> differences in yields
- Now - market research, finance, quality control

## Programming Languages

*To have a computer understand instructions & execute them*

- Fortran - the 1st programming language created
- Made for scientific and engineering calculations
- Led to the development of World Wide Web
- Revolutionized communication & learning

# Evolution of Data Science

**Inferential**

| < 1940s | 1940s - 50s | 1960s - 70s | 1980s - 90s | 2000s - 10s | 2020+ |
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| Central Tendency<br>Expected Values<br>Probability Theory | Bayesian Statistics<br>Sampling Theory<br>ANOVA | | | | |
| Telegraph<br>Difference Engine<br>Audio Tapes | Digital Computers<br>Monte Carlo Methods<br>Programming Languages | | | | |

**Computational**

# Evolution of Data Science (1960s-1970s)

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## Non-Parametric Methods

*Rely on ranking / ordering of data rather than the distribution*

- Frank Wilcoxon - Wilcoxon Rank-sum test
- Effect of store ambience on customer behaviour
- Sales difference b/w 2 groups in 2 different stores
- More effective marketing and pricing strategies

## Operating Systems

*A software that manages resources & apps in a computer*

- General Motors are responsible for creating the 1st OS
- GM-NAA I/O - designed for their IBM 704 mainframe
- To manage hardware and use them efficiently
- Today - Windows, MAC, Android, Linux are everywhere

## Decision Theory

*Assign probabilities to different outcomes to make a decision*

- Howard Raiffa - Economist - Negotiation Processes
- Government agencies - achieve favorable outcomes
- Identify optimal strategies using decision trees
- Improved negotiation - labor, international trade

## Databases & Storage

*Store, Organize & Query large amounts of data quickly*

- Charles Bachman - IBM - 1st DBMS ever created
- Businesses wanted databases to be standardized
- **Co**mmon **B**usiness **O**riented **L**anguage - COBOL
- Laid the roots for the creation of MySQL in 1995

## Robust Statistics

*Provide accurate results despite outliers/extreme values*

- John W Tukey - Statistician - Contributed to EDA
- Improve QC process - Identify and remove outliers
- Box plots - identify outliers and variation
- Manufacturing better products, lesser defects

## Time Sharing Systems

*Many users can access a computer at the same time!*

- **C**ompatible **T**ime-**S**haring **S**ystem (CTSS)
- Created by MIT to access one IBM computer
- The seed thought for modern networking systems
- Today's cloud exists because of the experiment!

# Evolution of Data Science

**Inferential**

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| Telegraph<br>Difference Engine<br>Audio Tapes | Digital Computers<br>Monte Carlo Methods<br>Programming Languages | Operating Systems<br>Databases & Storage<br>Time-sharing Systems | | | |

**Computational**

# Evolution of Data Science (1980s-1990s)

### Resampling Methods

*Simulate multiple datasets from original data for analysis*

- Bradley Efron- Bootstrap technique
- Market Research survey - calculate uncertainty of data
- Estimate sampling distribution + hypothesis testing
- More accurate estimates + better decision making

### Generalized Linear Models

*Analyze data where outcome is not normally distributed*

- John Nelder + Robert Wedderburn
- Insurance claim modeling - identify risk exposure
- Model different types of response variables
- More accurate + flexible modeling of several data types

### Model Selection Techniques

*Selecting best mathematical model for a process*

- Akaike - Akaike Information Criterion (AIC)
- Demand forecasting - accurate predictions
- AIC - Evaluate model - fit, explainability, accuracy
- Better model selection, improved prediction accuracy

### Personal Computers

*Small, lightweight, affordable - used by a single person*

- Altair 8880 - 1st PC - 1975 - company called MITS
- This was primitive - Apple II in 1977 made PCs popular
- Mostly used by hobbyists & technicians
- You could work & collaborate from anywhere

### Object-Oriented Programming

*An abstract entity with its own set of properties & functions*

- Popularized by C++ and Java
- Revolutionized software development
- Flexible, Modular, Reusable & Easy to maintain codes
- Browsers, apps, games - Impossible w/o OOP

### Advanced Programming Languages

*High level - data structures - loops - objects - conditions*

- Earliest was Fortran - created in the mid 50s
- Laid the foundation for Java, Ruby, and Python
- Able to create complex applications - at scale
- Democratization of programming - Anybody can Code!

# Evolution of Data Science

**Inferential**

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**Computational**

# Evolution of Data Science (2000s-2010s)

## Bayesian Networks & Graphical Models

*Relationship b/w variables in a dataset using graphs*

- Judea Pearl - Directed Acyclic Graphs - Turing award
- Healthcare - chances of patient having a disease
- Easily interpret complex relationship b/w variables
- Accurate diagnosis + improved outcomes, decisions

## Artificial Intelligence & Machine Learning

*Machines responding/doing tasks at human level intelligence*

- Alan Turing - Machine Intelligence - Imitation Game
- Frank Rosenblatt - “Built the Perceptron” - late 50s
- 2012: Geoffrey Hinton - “Deep Neural Networks”
- 2016: AlphaGo defeats Human Go Champion

## Causal Inference

*Is change in one variable changing the other?*

- Rubin - Rubin Causal Model
- Education - Summer program on student outcomes
- Using outcomes to represent causal relationship
- Better understanding of variables + decision making

## Big Data

*Massive digital information generated every second*

- Nutch Search Engine - Optimize speed of search
- Doug Cutting, 2005: Hadoop (son’s toy elephant)
- Paved the way for in-memory computing: Spark
- Big Data Analytics - started with Google & Facebook

## Open Science Movement

*Making research accessible, collaborative, transparent*

- Eli Lilly - Open Innovation Drug Discovery (OIDD)
- Pharma - Develop new drugs and treatments
- Greater collaboration, transparency, reproducibility
- Faster drug development + therapies

## Cloud Computing

*Computing power & resources for everyone, on-demand*

- Coined by Eric Schmitt - 2006, Google CEO
- 2006: **A**mazon **W**eb **S**ervices, the 1st cloud provider
- Followed by Microsoft Azure and Google Cloud
- Grew due to the reduction to cost of computing

# Evolution of Data Science

**Inferential**

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**Computational**

# Evolution of Data Science (2020s+)

## Interdisciplinary Approaches

*Knowledge from multiple disciplines for problem solving*

- Tesla - advances in battery + electric motor tech
- Model S - range of 400 km in a single charge
- Accelerated transition from fossil fuels
- Innovative solutions to complex problems

## Blockchain

*Share information - secure, transparent, & tamper-proof*

- Created for the proposal of a Virtual Currency System
- 2008: BitCoin - underlying tech was Blockchain
- The concept is a threat for Traditional Banking Systems
- Extreme Security + Low Fees (No Central Authority)

## Newer Causal Inference methods

*Making causal inference accurate and reliable*

- Amazon - Personalized Marketing Campaigns
- Recommend products likely to be purchased
- Causal Inference methods - analyse user behavior
- Increased sales, customer satisfaction

## Edge Computing

*Compute directly at the source of data, instead of remote*

- Took shape in the early 2000s - **I**nternet **o**f **T**hings (IoT)
- Tesla's advancements with Autonomous Vehicles
- Opportunities: Real time monitoring & analysis (Medical Devices, Defence, Smart Homes)

## Natural Experiments

*Observe events naturally occuring w/o manipulating factors*

- Journal of Public Economics - study of policy impact
- Effectiveness of Public health interventions
- Impact of business closure due to pandemic on jobs
- Investigate complex phenomena + precise conclusions

## Quantum Computing

*Use the principles of quantum physics to compute*

- 1st built in 1998 - Los Alamos Laboratory New Mexico
- Impact areas: Cryptography, Chemistry & Optimization
- In early stages, a lot of opportunities are still theoretical and under experimentation

# Evolution of Data Science

**Inferential**

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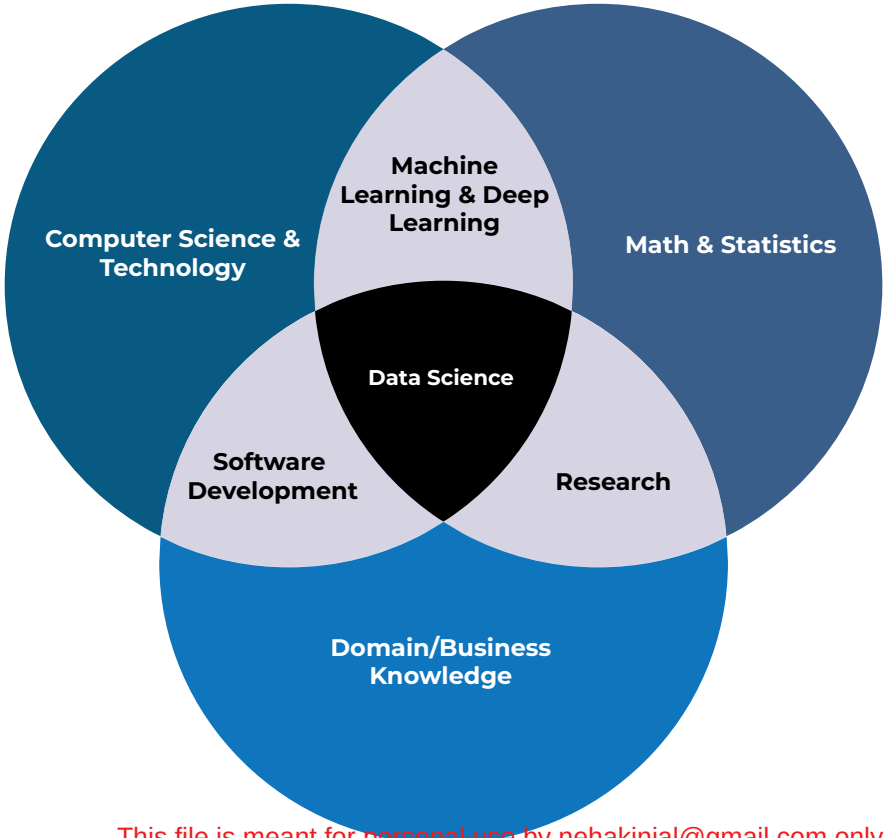
**Computational**

# Questions?

# Let’s conclude by defining data science...

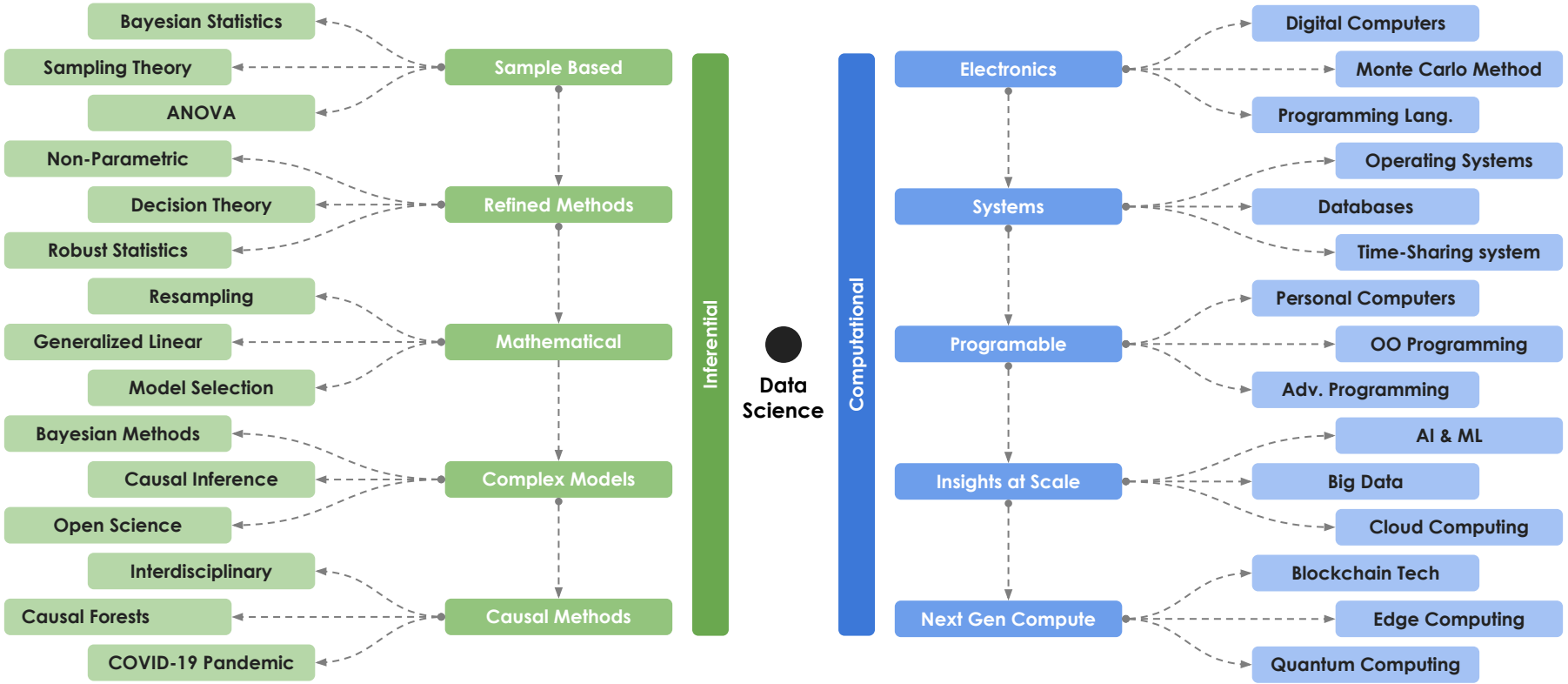


Great Learning

# Happy Learning !

# Appendix

# Summary - mind map of the history



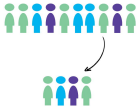
# Evolution of Data Science (1940s-1950s)

## Inferential

### Bayesian Statistics

- Analysis of data and the inference of probabilities
- **How?** - Using Bayes' theorem

### Sampling Theory



- Challenges will large populations
- **How?** - Drawing inferences from small subsets

### ANOVA

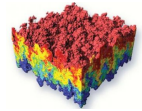
- Test for significant differences between groups
- **How?** - variability within and between the groups

## Computational

### Digital Computers

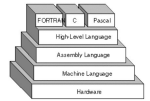
- First electronic digital computers
- **How ?** - Developments in electronic computing technology

### Monte Carlo Methods



- To simulate the behavior of the process
- **How?** - Model is created using probability distributions

### Programming Languages




- Automate complex calculations and tasks
- **How?** - Fortran & COBOL were discovered

# Evolution of Data Science (1960s-1970s)

## Inferential

### Non-parametric methods

- When data do not meet the standard assumptions
- **How?** - by using techniques like ranking

### Decision Theory


- Framework for making decisions under uncertainty
- **How?** - evaluating and choosing best alternatives

### Robust Statistics

- Methods less sensitive to violations of assumptions
- **How?** - resisting to outliers & other non-normality

## Computational

### Operating systems

- Manages hardware and software resources
- **How ?** - using device drivers, system libraries, and system utilities

### Databases

- Tool for managing/analyzing large data.
- **How?** - using tables, queries, indexes

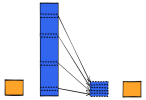
### Time-sharing systems

- System to access computer simultaneously
- **How?** - by dividing the computing resources

# Evolution of Data Science (1980s-1990s)

## Inferential

### Resampling Methods



- To evaluate the performance of a statistical model
- **How?** - Using Bootstrap/Cross validation resampling

### Generalized Linear Models

- To handle variety of variables & error distributions
- **How?** - connecting predictor function to the expected value of the response variable

### Model Selection Techniques

- To select the best statistical model
- **How?** - using techniques like AIC and BIC

## Computational

### Personal computers

- Computer designed for use by an individual
- **How ?** - using small, programmable computing devices

### Object-Oriented Programming

- "objects" to represent data and functionality
- **How?** - using blueprints of behaviors of the objects

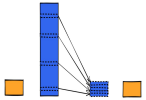
### Advanced Programming Languages


- Address the limitations of earlier languages
- **How?** - C++, Python, and Java

# Evolution of Data Science (2000s-2010s)

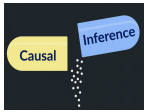
## Inferential

### Bayesian Networks & graphical Models



- Probabilistic representation of complex relationships
- **How?** - Using graphs to represent the relationships

### Causal Inference




- Analyzing how one event/action leads to another
- **How?** - Using techniques like DID & IV

### Open Science Movement


- emphasizing transparency, and community-driven innovation
- **How?** - by making things freely available

## Computational

### Artificial Intelligence and Machine Learning

- Enables to make predictions/decisions
- **How ?** - Utilizing large amounts of data

### Big Data


- Large and complex data sets
- **How?** - generated by digital systems & applications

### Cloud Computing

- Delivery of on-demand computing services
- **How?** - through service based model

# Evolution of Data Science (2020+)

## Inferential

### Interdisciplinary Approaches

- Pandemic highlighted the need for collaboration
- Healthcare, data science, Epidemiology, genetics, etc.

### Newer Causal Inference Methods


- Developing new causal inference methods
- COVID-19 pandemic / new data sources

### Natural Experiments

- Brought inferential statistics into public eye
- Understanding the spread of virus/predicting trends

## Computational

### Blockchain technology

- Secure & transparent storage/transfer of data
- **How?** - creating a digital ledger that records transactions

### Edge Computing

- Computing directly at the source of data
- **How?** - Deploy resources within the product

### Quantum Computing

- Providing more processing power
- **How?** - use quantum bits or qubits

# Why data science?