

UMD DATA605: Big Data Systems

Lesson 1.2: Introduction to Big Data

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Data Science

- Promises of data science
 - Give a competitive advantages
 - Make better strategic and tactical business decisions
 - Optimize business processes
- Data science is not new, it was called:
 - Operation research (~1970-80s)
 - Decision support, business intelligence (~1990s)
 - Predictive analytics (Early 2010s)
 - . .
- What has changed
 - Now learning and applying data science is easy
 - No need for hiring a consulting company
 - Tools are *open-source*
 - E.g., Python + pydata stack (numpy, scipy, Pandas, sklearn)
 - Large data sets available
 - Cheap computing
 - E.g., cloud computing (AWS, Google Cloud), GPUs



Motivation: Data Overload

- "Data science is the number one catalyst for economic growth" (McKinsey, 2013)
- Explosion of data in every domain
 - Sensing devices/networks monitor processes 24/7
 - E.g., temperature of your room, your vital signs, pollution in the air
 - Sophisticated smart-phones
 - 80%+ of the world population has a smart-phone
 - Internet and social networks make it easy to publish data
 - Internet of Things (IoT): everything is connected to the internet
 - E.g., power supply, toasters
 - Datafication turns all aspects of life into data
 - E.g., what you like/enjoy turned into a stream of your "likes"
- Challenges
 - How to handle the increasing amount data?
 - How to extract actionable insights and scientific knowledge from data?



Scale of Data Size

- Megabyte = $2^{20} \approx 10^6$ bytes
 - Typical English book
- **Gigabyte** = 2³⁰ bytes = 1,000 MB
 - 1/2 hour of video
 - Wikipedia (compressed, no media) is 22GB
- Terabyte = 1 million MB
 - Human genome: ~1 TB
 - 100,000 photos
 - \$50 for 1TB HDD, \$23/mo on AWS S3
- Petabyte = 1000 TB
 - 13 years of HD video
 - \$250k/year on AWS S3

- Exabyte = 1M TB
 - Global yearly Internet traffic in 2004
- Zettabyte = 1B TB = 10^{21} bytes
 - Global yearly Internet traffic in 2016
 - Fill 20% of Manhattan, New York with data centers
- **Yottabytes** = 10²⁴ bytes
 - Yottabyte costs \$100T
 - Fill Delaware and Rhode Island with a million data centers
- Brontobytes = 10²⁷ bytes



Constants Everybody Should Know

• CPU at 3GHz: 0.3 ns per instruction

L1 cache reference/register: 1 ns

• L2 cache reference: 4 ns

• Main memory reference: 100 ns

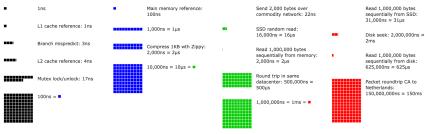
• Read 1MB from memory: 20-100 us

• SSD random read: 16 us

• Send 1KB over network: 1 ms

• Disk seek: 2 ms

Packet round-trip CA to Netherlands: 150 ms





Big Data Applications: Marketing

- Personalized marketing
 - Target each consumer individually
 - E.g., Amazon personalizes suggestions using:
 - Shopping history
 - Search, click, browse activity
 - Other consumers and trends
 - Reviews (NLP and sentiment analysis)
- Brands want to understand customer-product relationships
 - Use sentiment analysis from:
 - · Social media, online reviews, blogs, surveys
 - Positive, negative, neutral sentiment
- E.g.,
 - In 2022, \$600B spent on digital marketing



Big Data Applications: Advertisement

Mobile advertisement

- Mobile phones are ubiquitous
- 80% of world population has one
- 6.5 billion smartphones
- Integrate online and offline databases, e.g.,
 - GPS location
 - Search history
 - Credit card transactions

• E.g.,

- You've bought a new house
- You google questions about house renovations
- You watch shows about renovations
- Your phone tracks where you are
- Google sends you coupons for the closest Home Depot
- "I feel like Google is following me"





Big Data Applications: Medicine

- Personalized medicine
 - Patients receive treatment tailored to them for efficacy
 - Genetics
 - · Daily activities
 - Environment
 - Habits
- Biomedical data
- Genome sequencing
- Health tech
 - Personal health trackers (e.g., smart rings, phones)



Big Data Applications: Smart Cities

- Smart cities
 - Interconnected mesh of sensors
 - E.g., traffic sensors, camera networks, satellites
- Goals
 - Monitor air pollution
 - Minimize traffic congestion
 - Optimal urban services
 - Maximize energy savings



Goal of Data Science

- Goal: from data to wisdom
 - Data (raw bytes)
 - Information (organized, structured)
 - Knowledge (learning)
 - Wisdom (understanding)
- Insights enable decisions and actions
- Combine streams of big data to generate new data
 - New data can be "big data" itself





The Six V'S of Big Data

- What makes "Big Data" big?
- Volume
 - Vast amount of data is generated
- Variety
 - Different forms
- Velocity
 - Speed of data generation
- Veracity
 - Biases, noise, abnormality in data
 - Uncertainty, trustworthiness
- Valence
 - Connectedness of data in the form of graphs
- Value
 - Data must be valuable
 - Benefit an organization





The Six V's of Big Data

Volume

- Exponentially increasing data
- 2.5 exabytes (1m TB) generated daily
 - 90% of data generated in last 2 years
 - Data doubles every 1.2 years
- Twitter/X: 500M tweets/day (2022)
- Google: 8.5B queries/day (2022)
- Meta: 4PB data/day (2022)
- Walmart: 2.5PB unstructured data/hour (2022)

Variety

- Different data forms
 - Structured (e.g., spreadsheets, relational data)
 - Semi-structured (e.g., text, sales receipts, class notes)
 - Unstructured (e.g., photos, videos)
- Different formats (e.g., binary, CSV, XML, JSON)



The Six V's of Big Data

Velocity

- Speed of data generation
 - E.g., sensors generate data streams
- Process data off-line or in real-time
- Real-time analytics: consume data as fast as generated

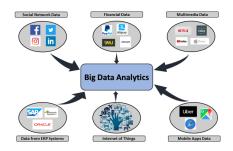
Veracity

- Relates to data quality
- How to remove noise and bad data?
- How to fill in missing values?
- What is an outlier?
- How do you decide what data to trust?



Sources of Big Data

- Distinguish Big Data by source
 - Machines
 - People
 - Organizations





Sources of Big Data: Machines

- Machines generate data
 - Real-time sensors (e.g., sensors on Boeing 787)
 - Cars
 - Website tracking
 - Personal health trackers
 - Scientific experiments
- Pros
 - Highly structured
- Cons
 - Difficult to move, computed in-place or centralized
 - Streaming, not batch



Sources of Big Data: People

- People and their activities generate data
 - Social media (Instagram, Twitter, LinkedIn)
 - Video sharing (YouTube, TikTok)
 - Blogging, website comments
 - Internet searches
 - Text messages (SMS, Whatsapp, Signal, Telegram)
 - Personal documents (Google Docs, emails)
- Pros
 - Enable personalization
 - Valuable for business intelligence
- Cons
 - Semi-structured or unstructured data
 - Text, images, movies
 - Requires investment to extract value
 - $\bullet \;\; \mathsf{Acquire} \to \mathsf{Store} \to \mathsf{Clean} \to \mathsf{Retrieve}$
 - $\rightarrow \mathsf{Process} \rightarrow \mathsf{Insights}$





Sources of Big Data: Organizations

Organizations generate data

- Commercial transactions
- Credit cards
- E-commerce
- Banking
- Medical records
- Website clicks
- Pros
 - · Highly structured
- Cons
 - Store every event to predict future
 - Miss opportunities
 - Stored in "data silos" with different models
 - Each department has own system
 - Additional complexity
 - Data outdated/not visible
 - Cloud computing helps (e.g., data lakes, data warehouses)

