Big Data

Understanding Volume, Velocity, and Variety

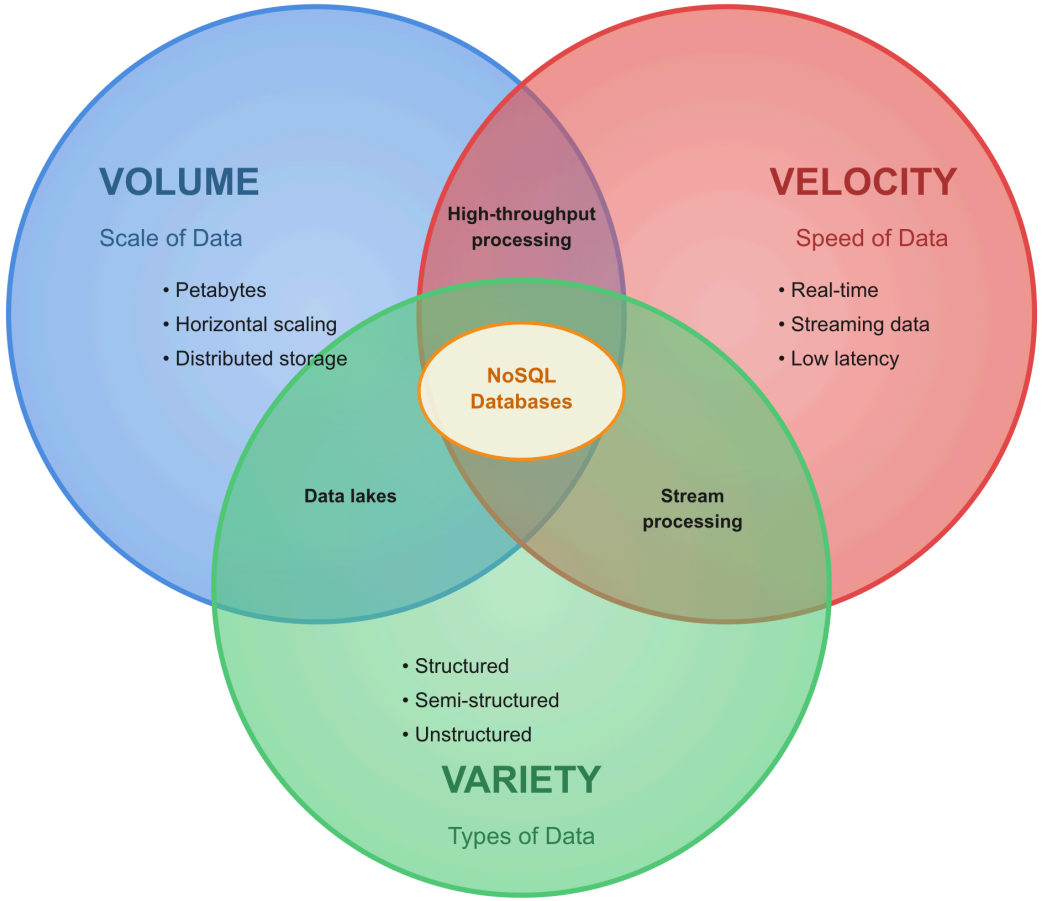
What is Big Data?

> **Big Data** refers to data that displays the characteristics of volume, velocity, and variety (**the 3 Vs**) to an extent that makes the data unsuitable for management by a relational database management system.

The 3 Vs of Big Data

- **Volume**: the quantity of data to be stored
- **Velocity**: the speed at which data is entering the system
- **Variety**: the variations in the structure of the data to be stored

Big Data Characteristics Diagram



Pioneers of Big Data Technology

Google (to index the web)

- Google File System (GFS)
- MapReduce (distributed data processing)
- BigTable (key-value store)

Amazon (for web commerce at scale)

- Dynamo (key-value store)

Facebook (for social graph processing)

- Cassandra

Today: Tech advancement has increased the opportunity for organizations to generate and track data (e.g. via personal connected devices)

Volume: Handling Large Amounts of Data

Units of Data Volume

Amount of Data	Name	Abbreviation
1024 bytes	kibibyte	KiB
1024 KiB	mebibyte	MiB
1024 MiB	gibibyte	GiB
1024 GiB	tebibyte	TiB
1024 TiB	pebibyte	PiB
1024 PiB	exbibyte	EiB
1024 EiB	zebibyte	ZiB

Note: kibi-, mibi-, gibi- etc. increase by 1024x (2^{10}), while kilo-, mega-, giga- increase by 1000x

Scale of Modern Storage

- The largest storage systems today (e.g., cloud storage at Amazon, Google, Microsoft) are approaching a **Zebibyte**
- That's 1,024 Exbibytes!
- Or approximately 1,180,591,620,717,411,303,424 bytes

Two Approaches to Handle Volume

Scale Up (Vertical Scaling)

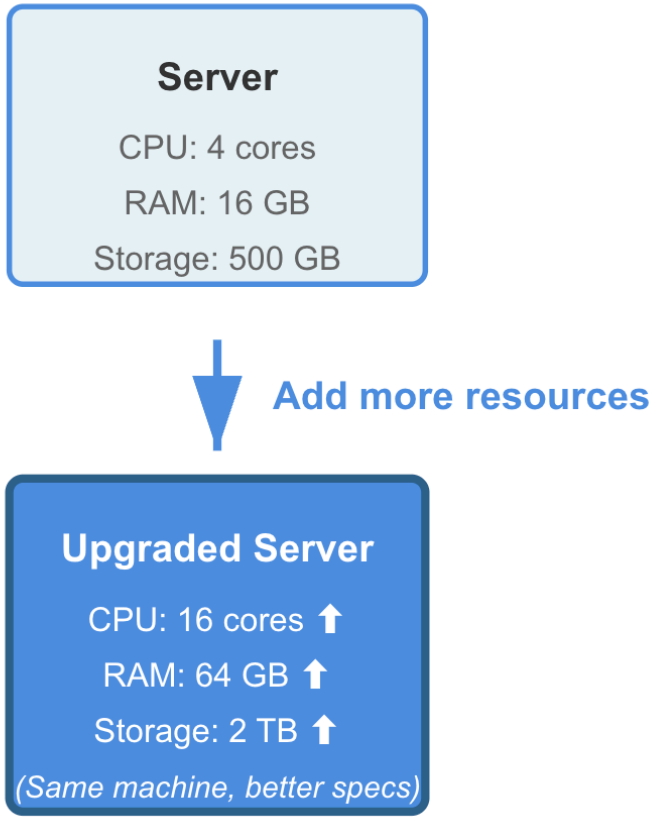
- Increase the CPU, RAM, Disk of each storage machine
- Keep the number of machines fixed

Scale Out (Horizontal Scaling)

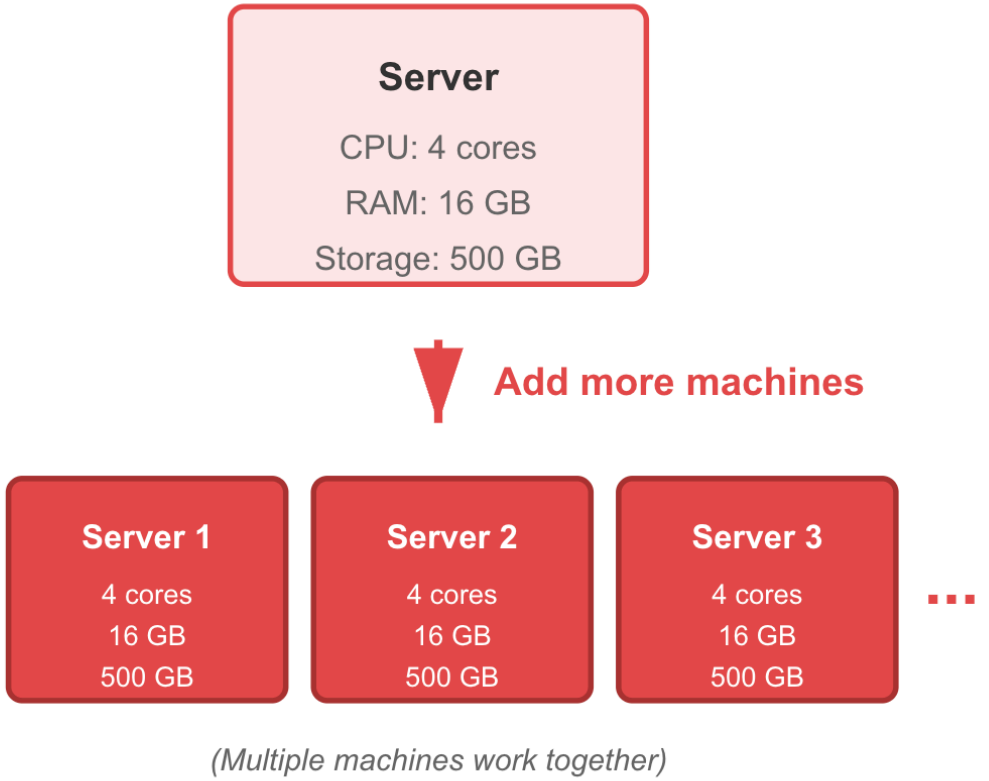
- Keep the CPU, RAM, Disk of each machine fixed
- Increase the number of machines

Scaling Approaches Visualized

Vertical Scaling (Scale Up)



Horizontal Scaling (Scale Out)



Comparing Scaling Approaches

	Capacity	Cost	Coordination
Scale Up	👎 machine limit	👎 specialized hw	👍 few machines
Scale Out	👍 add machines	👍 commodity hw	👎 many machines

Why RDBMS Struggles with Volume

- **RDBMS requires high coordination**
  - Tables are related via common attributes
  - Maintaining referential integrity across distributed systems is challenging
- **Can only scale up**
  - Limited by physical machine constraints
  - Results in lower capacity and higher cost
- **Result**: RDBMS is unsuitable for Big Data Volume

NoSQL: The Volume Solution

- **NoSQL compromises on relational power**
  - Limited transaction support
- **In return, can scale out**
  - Add more commodity hardware
  - Higher capacity at lower cost
  - Better suited for handling volume

Velocity: Handling Speed of Data

Velocity Challenge Example

- **Example**: A cloud storage system like Google Cloud Storage handles **~10 million requests per second**
- **Problem**: If a scaled-up machine can handle ~10,000 requests per second, you would need **1,000 machines**!

Velocity Requires Scaling Out

- High velocity cannot be handled by a single machine
- **Must scale out** (same as for volume)
- RDBMS is not a good fit for velocity challenges
- NoSQL systems designed for distributed request handling

Variety: Handling Different Data Types

Structured vs. Unstructured Data

Structured Data

- Data that conforms to a predefined model (e.g., a table schema)
- RDBMS requires this!

Unstructured Data

- Can be anything, does not conform to a model
- Examples: videos, texts, emails, sensor data, social media posts

Semi-structured Data

- Parts are structured and parts are unstructured
- Examples: JSON documents, XML files

The Real World Challenge

- The real world is **full of unstructured data**
- Most valuable data doesn't fit neatly into tables
- Examples:
  - Customer reviews (text)
  - Product images (binary)
  - Click streams (logs)
  - IoT sensor readings (time series)

NoSQL Approach to Variety

Flexible Schema

- Ingest unstructured data first
- Impose structure as needed for applications
- Structure during retrieval and processing, not storage

Benefits

- Adapt to changing data formats
- Store diverse data types together
- No upfront schema design required

Key Takeaways

1. Big Data is defined by the **3 Vs**: Volume, Velocity, and Variety
2. **Scaling Out** (horizontal) is preferred over Scaling Up (vertical) for Big Data
3. **RDBMS** struggles with Big Data because it requires high coordination and structured data
4. **NoSQL** trades relational power for the ability to scale out and handle variety
5. Modern cloud storage systems are approaching **Zebibyte** scale