Data Storage

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Data Engineering 2024 Fall

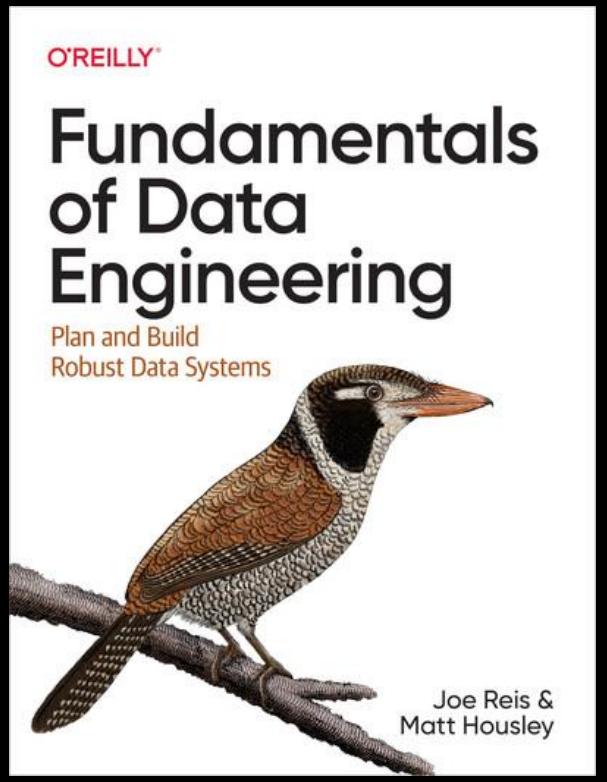
UNIVERSITY OF TARTU

Agenda

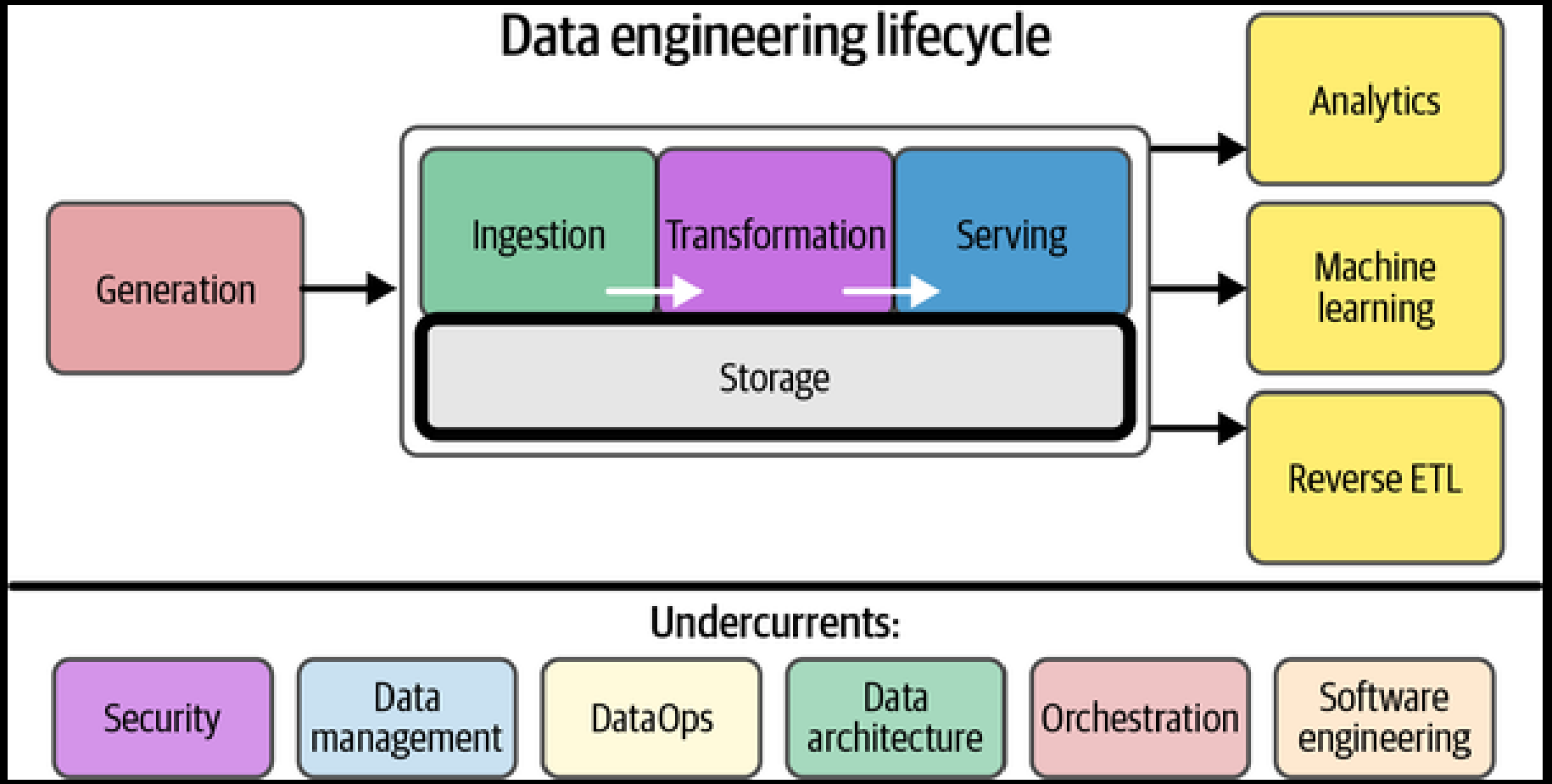
- Storage technologies
- Storage systems
- Data orientation
- Quiz session

Reading

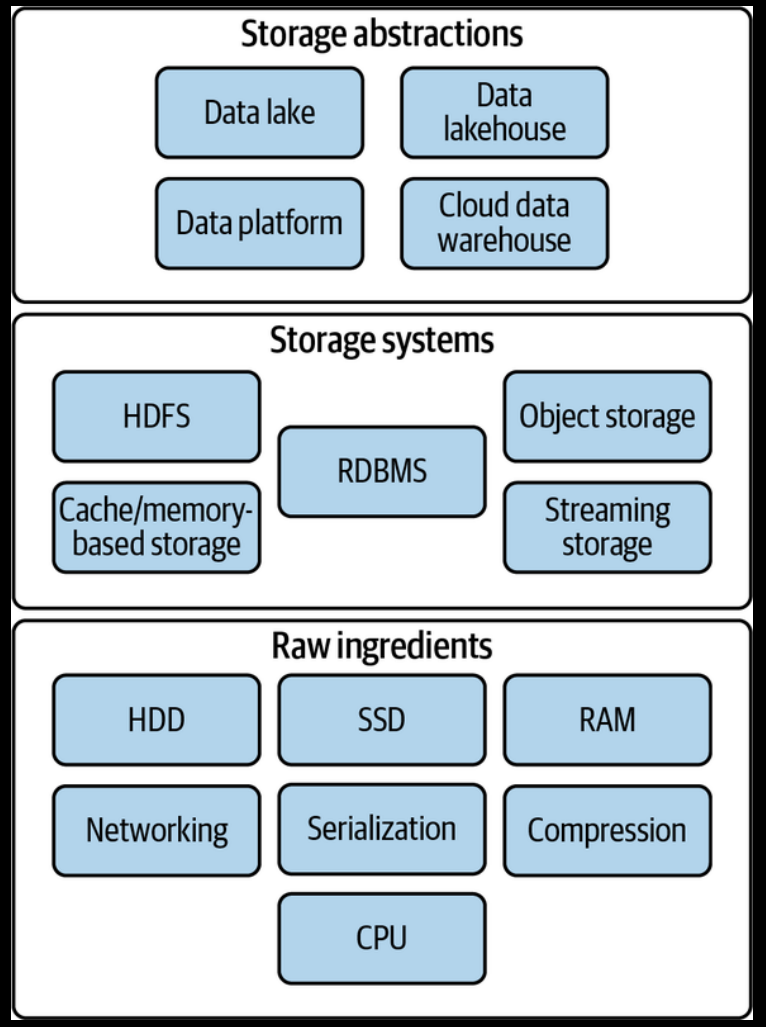
- Chapter VI



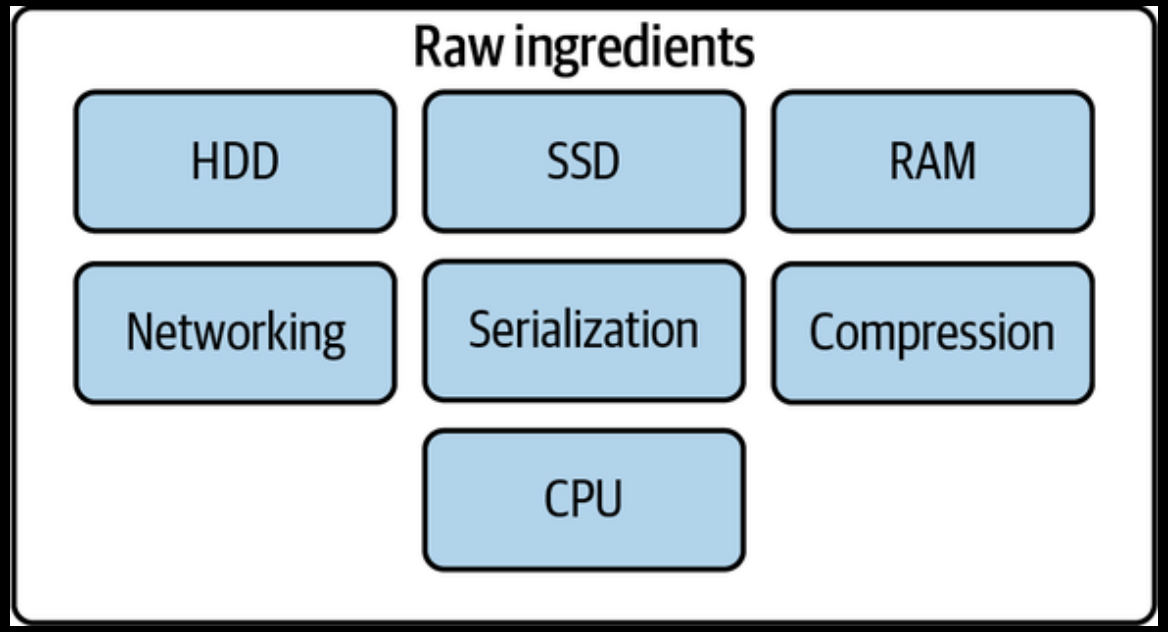
Storage technologies



Storage technologies



Storage technologies



Storage technologies

Storage type	Data fetch latency	Bandwidth	Price
CPU cache	1 nanosecond	1 TB/s	N/A
RAM	0.1 microseconds	100 GB/s	$10/GB
SSD	0.1 milliseconds	4 GB/s	$0.20/GB
HDD	4 milliseconds	300 MB/s	$0.03/GB
Object storage	100 milliseconds	10 GB/s	$0.02/GB per month
Archival storage	12 hours	Same as object storage once data is available	$0.004/GB per month

Table 6-1. A heuristic cache hierarchy displaying storage types with approximate pricing and performance characteristics

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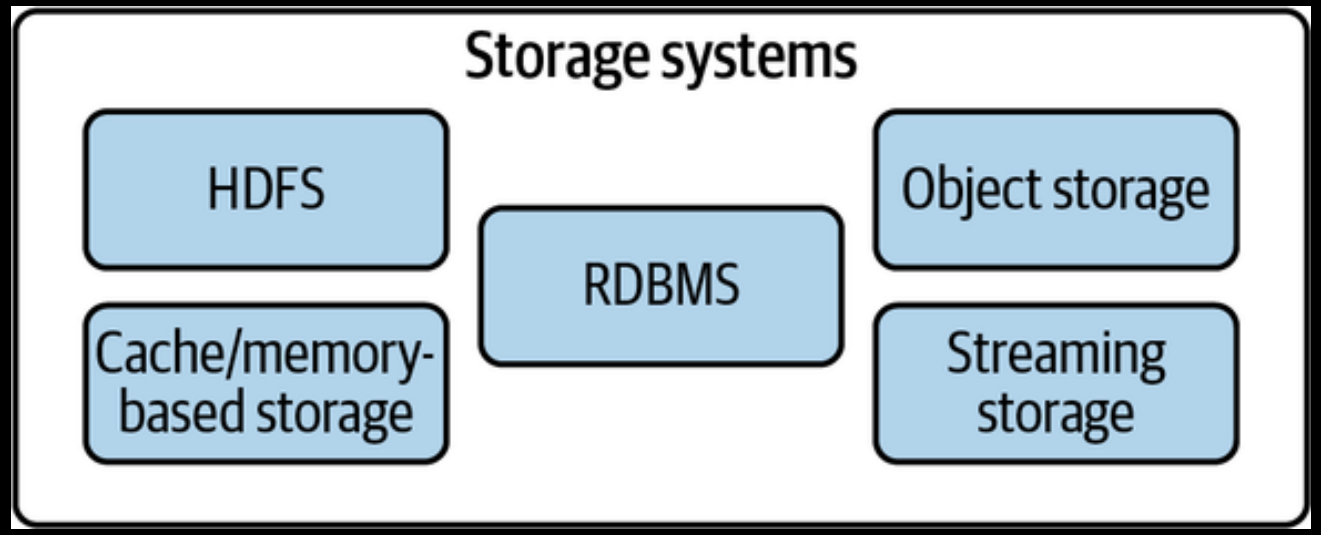
Storage systems

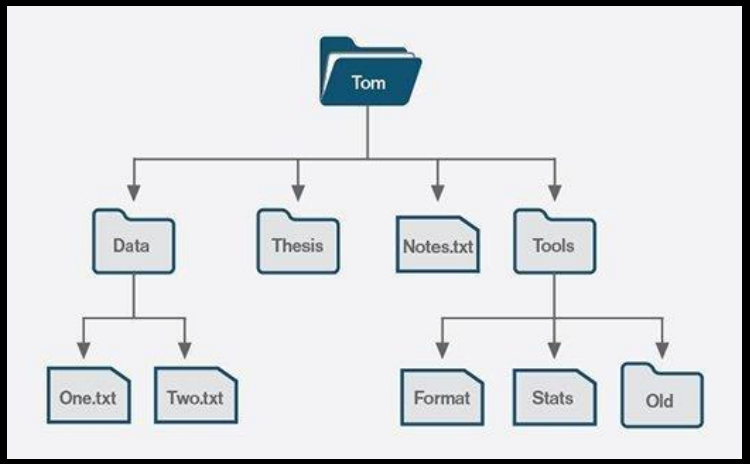


Storage systems

File storage

- Finite length
  - A file is a finite-length stream of bytes.
- Append operations
  - We can append bytes to the file up to the limits of the host storage system.
- Random access
  - We can read from any location in the file or write updates to any location.

Organized into a directory tree



https://www.techtarget.com/searchstorage/definition/file-system

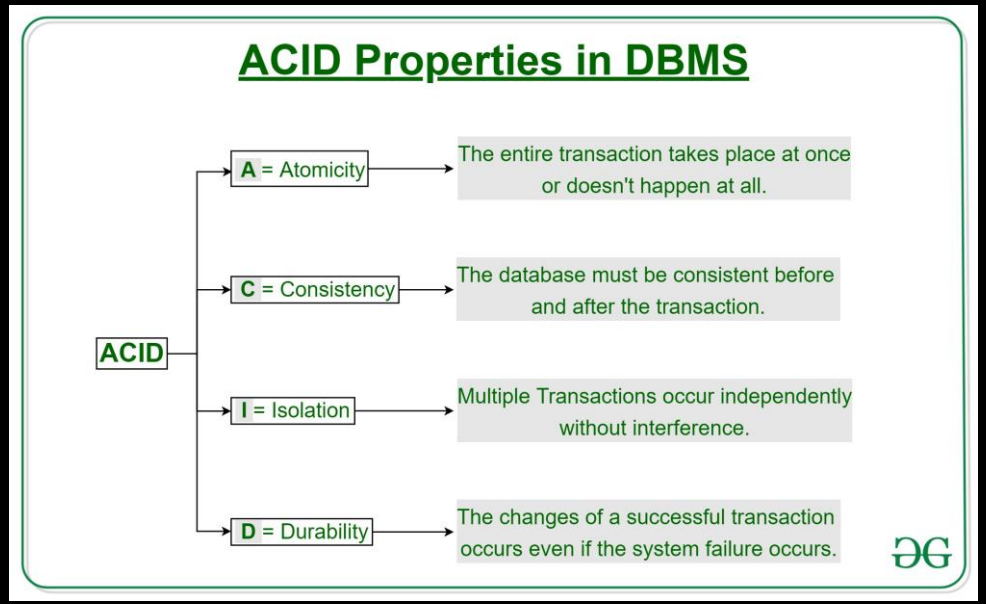
Storage systems

Block storage

- Fundamental raw storage
  - Used by HDD, SSD
- Finite size
  - 1 block = 512 bytes historically, now up to 4KB

Most RDBMS also use block storage:

ACID compliance

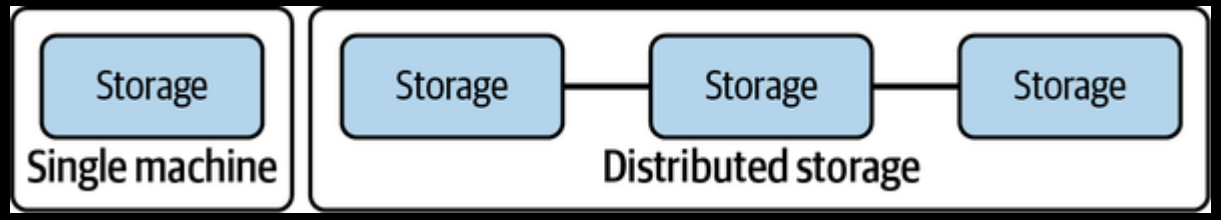


https://www.geeksforgeeks.org/acid-properties-in-dbms/

Storage systems

HDFS (Hadoop Distributed File System)

- Compute & storage on same nodes
  - Namenode & datanodes
- "Blocks"
  - Default 128MB, 3x replication



BASE

- Basically Available
  - Consistency is not guaranteed, but available most of the time
- Soft-state
  - Transaction state is fuzzy
- Eventual consistency
  - At some point, reading data will return consistent values.

Storage systems

Object storage

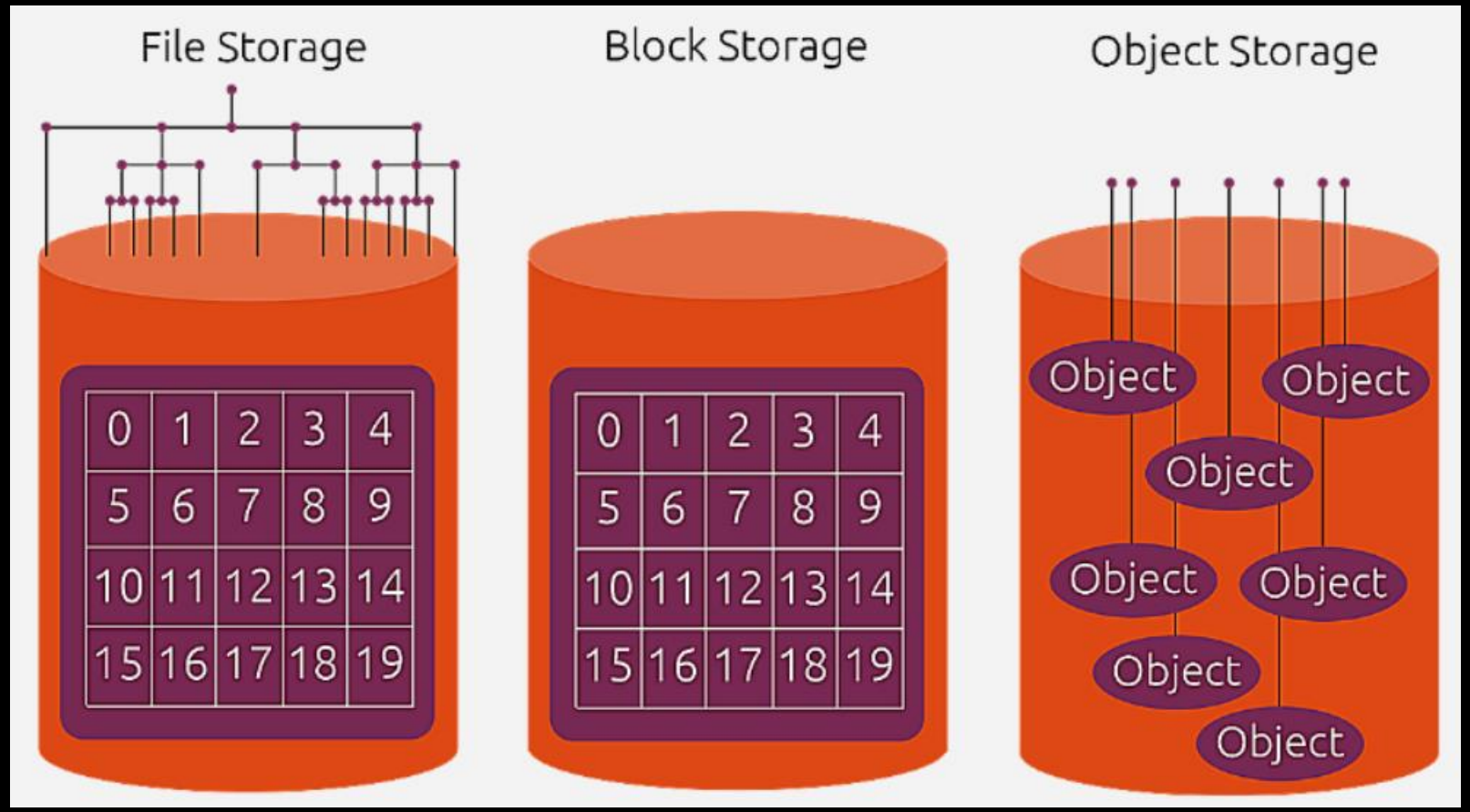
- Typical state-of-the-art cloud storage mechanism
  - Stores any kind of data
- Key-value store
  - NB! There are no “directories”
- Immutable data
  - Versioning
  - Consistency
- Also BASE

Storage systems

Cache and Memory-Based Storage Systems

- RAM-based storage
  - Serve data with fast latency
- Not durable
- Examples
  - Memcached, Redis

Storage systems



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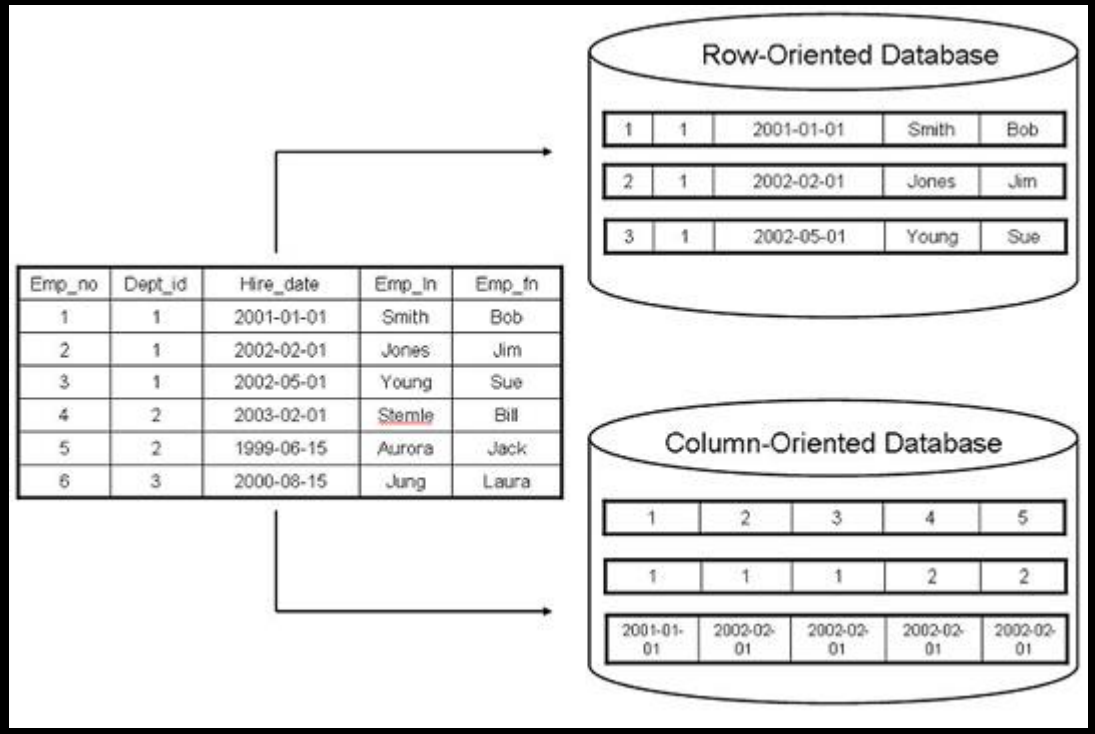
Data orientation

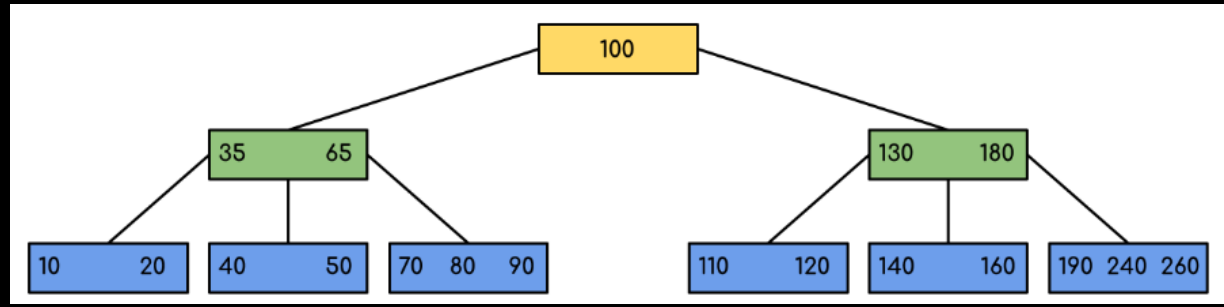
- Rows vs columns
  - Rows
    - OLTP
    - Updating single records
    - Access complete record
  - Columns
    - OLAP
    - Many columns
    - Aggregations



https://bi-insider.com/business-intelligence/column-and-row-based-database-storage/

Data orientation

- Indexing
  - OLTP
- Partitioning
  - OLAP, divide table into smaller parts
- Clustering
  - OLAP, group and order data within partition



Clustered and Partitioned Tables

Orders table
Not Clustered; Not partitioned

Order_Date	Country	Status
2022-08-02	US	Shipped
2022-08-04	JP	Shipped
2022-08-05	UK	Canceled
2022-08-06	KE	Shipped
2022-08-02	KE	Canceled
2022-08-05	US	Processing
2022-08-04	JP	Processing
2022-08-04	KE	Shipped
2022-08-06	UK	Canceled
2022-08-02	UK	Processing
2022-08-05	JP	Canceled
2022-08-06	UK	Processing
2022-08-05	US	Shipped
2022-08-06	JP	Processing
2022-08-02	KE	Shipped
2022-08-04	US	Shipped

Orders table
Clustered by Country; Not partitioned

Order_Date	Country	Status
2022-08-04	JP	Shipped
2022-08-04	JP	Processing
2022-08-05	JP	Canceled
2022-08-06	JP	Processing
2022-08-06	KE	Shipped
2022-08-02	KE	Canceled
2022-08-04	KE	Shipped
2022-08-02	KE	Shipped
2022-08-05	UK	Processing
2022-08-06	UK	Canceled
2022-08-02	UK	Canceled
2022-08-06	UK	Processing
2022-08-02	US	Shipped
2022-08-05	US	Processing
2022-08-05	US	Shipped
2022-08-04	US	Shipped

Orders table
Clustered by Country; Partitioned by Order_Date (Daily)

	Order_Date	Country	Status
Partition: 2022-08-02	2022-08-02	KE	Shipped
	2022-08-02	KE	Canceled
Clusters: Country	2022-08-02	UK	Processing
	2022-08-02	US	Shipped

	Order_Date	Country	Status
Partition: 2022-08-04	2022-08-04	JP	Shipped
	2022-08-04	JP	Processing
Cluster: Country	2022-08-04	KE	Shipped
	2022-08-04	US	Shipped

	Order_Date	Country	Status
Partition: 2022-08-05	2022-08-05	JP	Canceled
	2022-08-05	UK	Canceled
Cluster: Country	2022-08-05	US	Shipped
	2022-08-05	US	Processing

	Order_Date	Country	Status
Partition: 2022-08-06	2022-08-06	JP	Processing
	2022-08-06	KE	Shipped
Cluster: Country	2022-08-06	UK	Canceled
	2022-08-06	UK	Processing

https://cloud.google.com/bigquery/docs/partitioned-tables

https://www.geeksforgeeks.org/introduction-of-b-tree-2/

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Further reading

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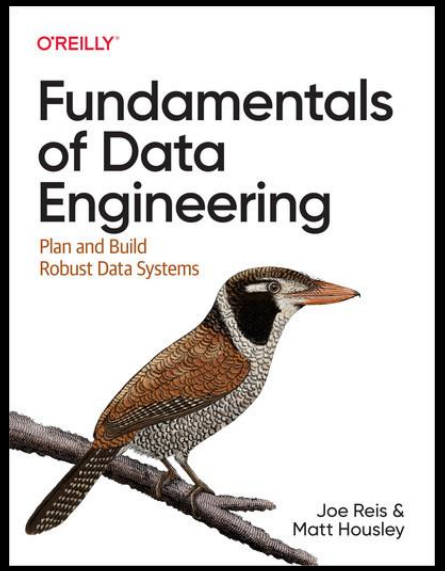

- https://medium.com/@ikramzouaoui95/data-storage-a-simple-explanation-of-column-oriented-vs-row-oriented-systems-758340c12f0e