

(Big) Data Engineering In Depth

From Beginner to Professional

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Senior Big Data Engineer

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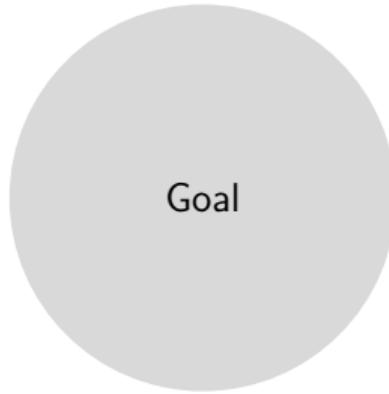
 mustafa.alaa.mohamed@gmail.com

¹Big Data & Analytics Department, Epam Systems

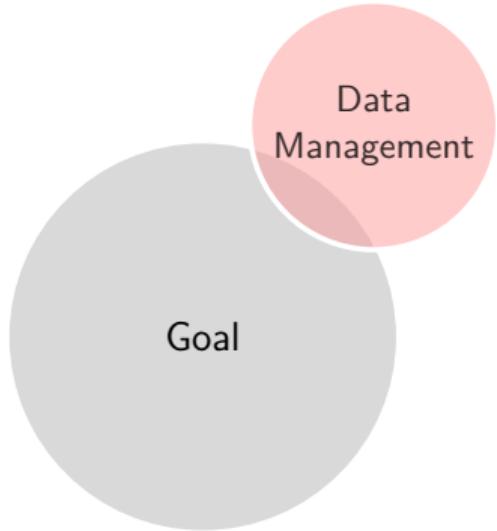
The Definitive Guide to Big Data Engineering Tasks

Course Introduction

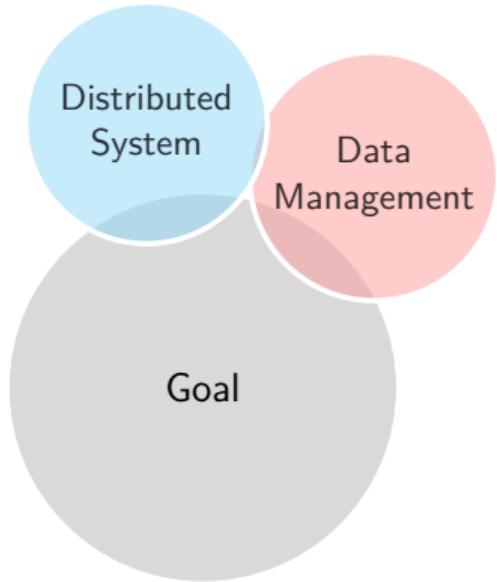
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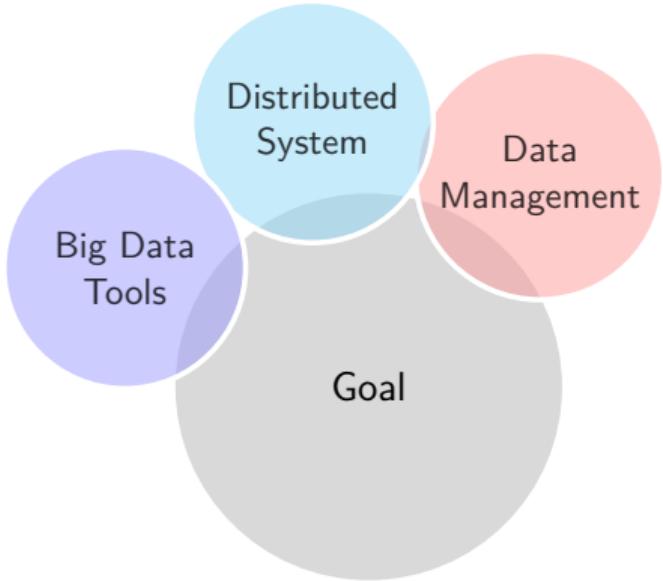
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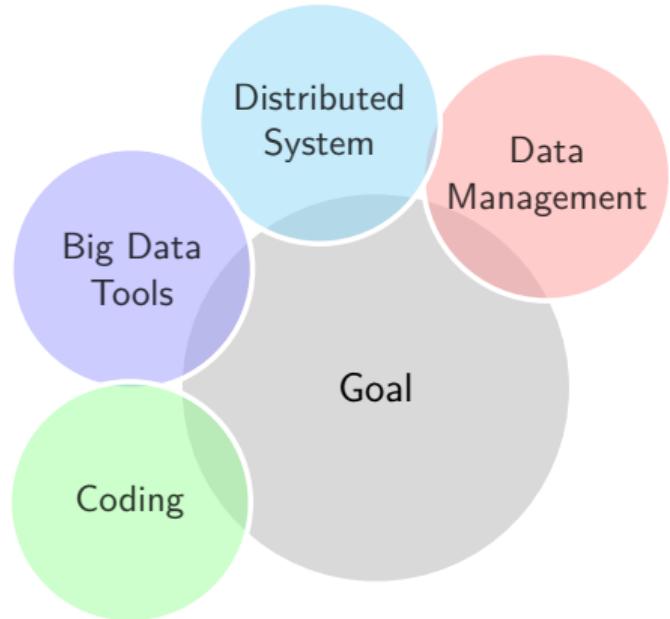
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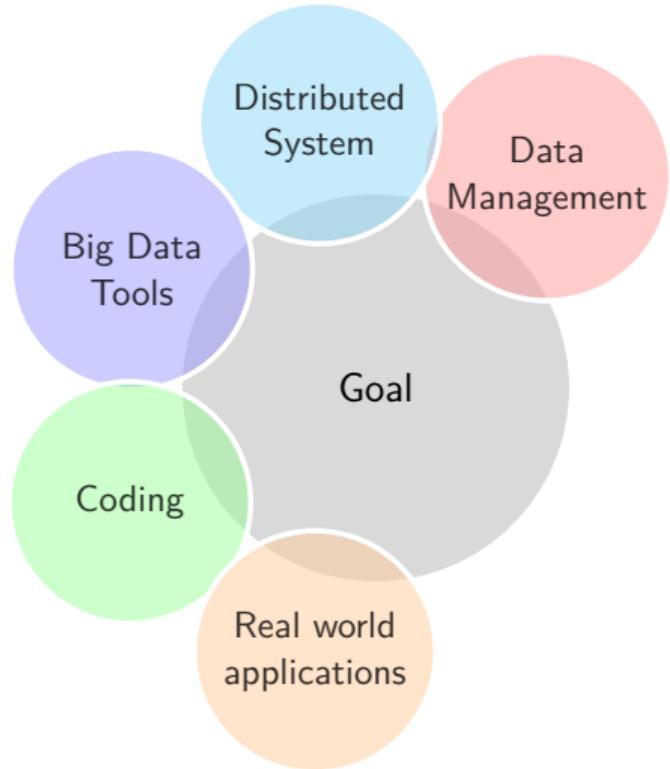
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Learning Objectives and Audience

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- Understanding of the DevOps tools and functions in data life-cycle.

Audience: Who Should Take This Course?

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- DevOps engineers who needs to understand the concepts of big data.
- Business or entrepreneur who needs to get more information about how to build or manage a data product.

Getting max benefit from this course

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Take the course advantage

- Follow the videos order as described.

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- Ask your questions.
- Join the online meeting or discussions.

Chapter Dependencies

You MUST finish the red chapters first

Ch.01 Introduction

Finish colors group before move to the next.

Ch.02 Data Management

Ch.03 Distributed Systems

Ch.04 Hadoop and MR

Ch.05 FN and Scala

Ch.06 Spark

Ch.07 Big Data Application

Ch.08 Massging Systems

Ch.09 Data Orchestration

Ch.10 NoSql

Ch.11 Elastic

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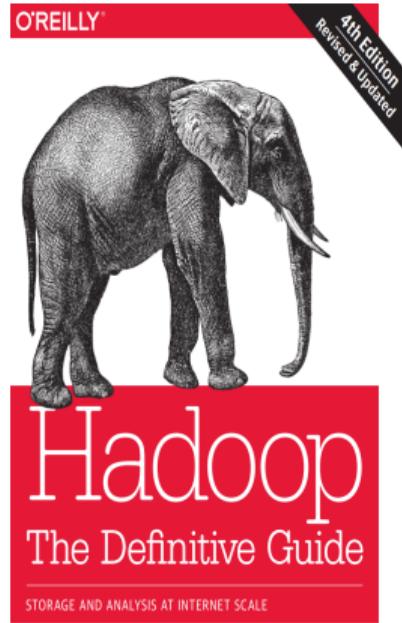
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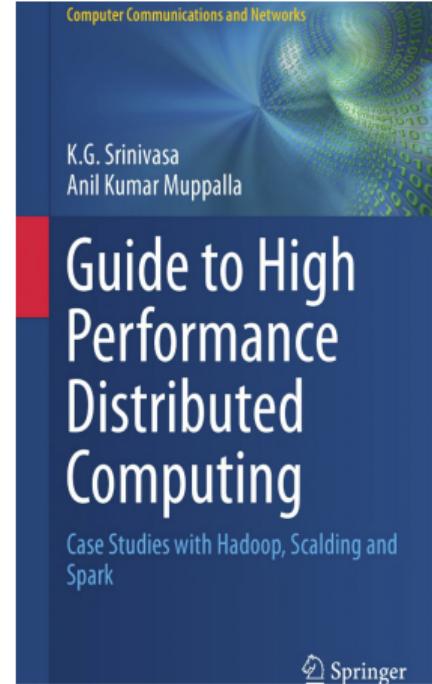
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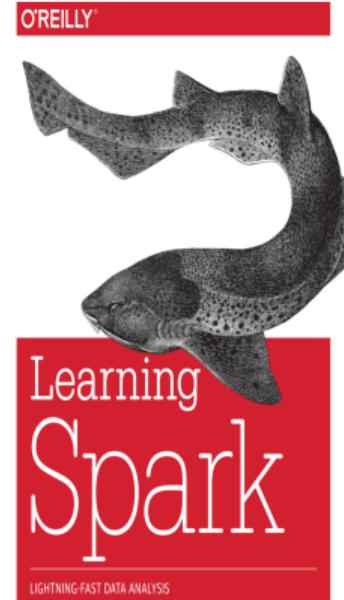
Textbooks-1



Tom White



Textbooks-2



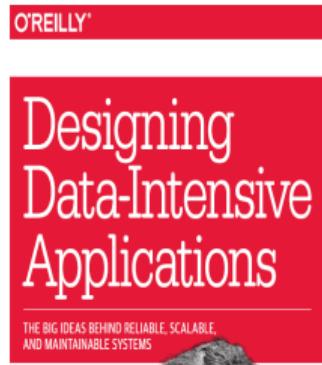
Textbooks-3



Neha Narkhede,
Gwen Shapira & Todd Palino



Jeff Carpenter & Eben Hewitt



Martin Kleppmann



Ugly but important

- User stories or technical discussions are not related to any of my current work or my previous companies.



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- User stories or technical discussions are not related to any of my current work or my previous companies.
- I am working at EPAM Systems. My company approved me for doing this online course public but the materials are not reviewed or assessed by my company. It is on my own responsibilities.

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Introduction To Data Management and Data Warehouse

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- What is the data modeling and its design?



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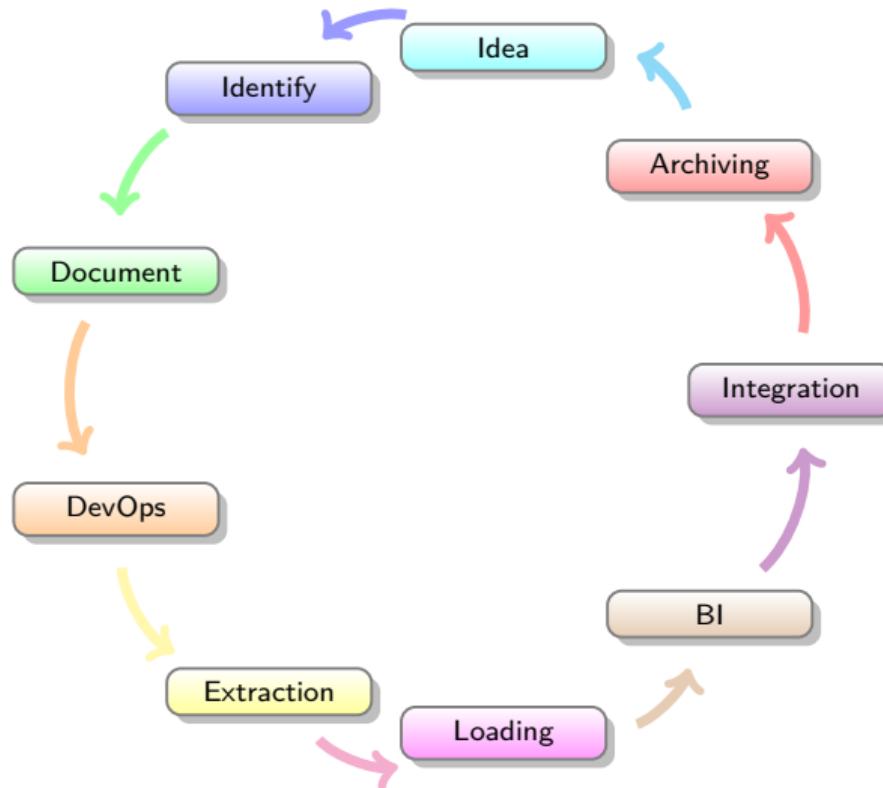
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 - Data retention or **archiving** process ex: (Hot or Cold storage).

Data Management Life-Cycle



Data Abstraction

Motivation to Data Layers (Use Case)

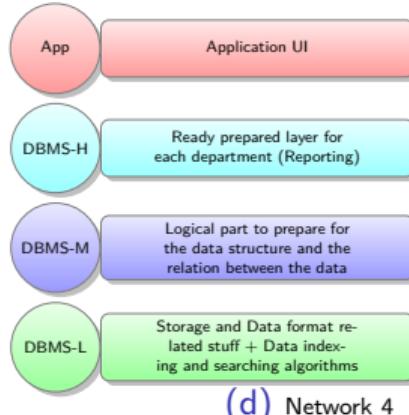
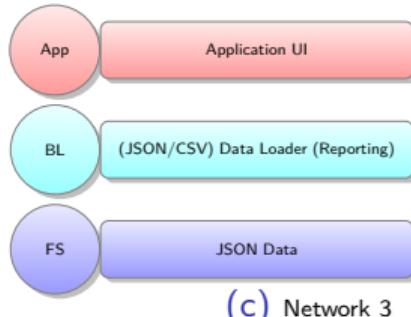
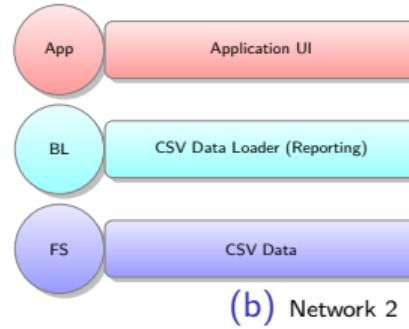
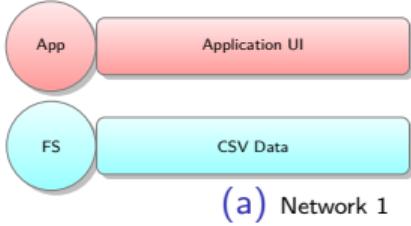
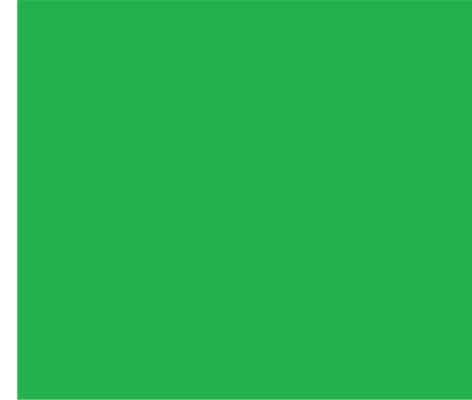


Figure: The average and standard deviation of critical parameters: Region R4

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- To answer these questions you need to understand the data layers.

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- The process of **hiding** irrelevant details from developer (user) is called data **abstraction**.

Data Layers (Abstraction)

Definition

Data Abstraction and Data Independence: DBMS comprise of complex data-structures. In order to make the system efficient in terms of retrieval of data, and reduce complexity in terms of usability of users, developers use abstraction i.e. hide irrelevant details from the users. This approach simplifies database design.

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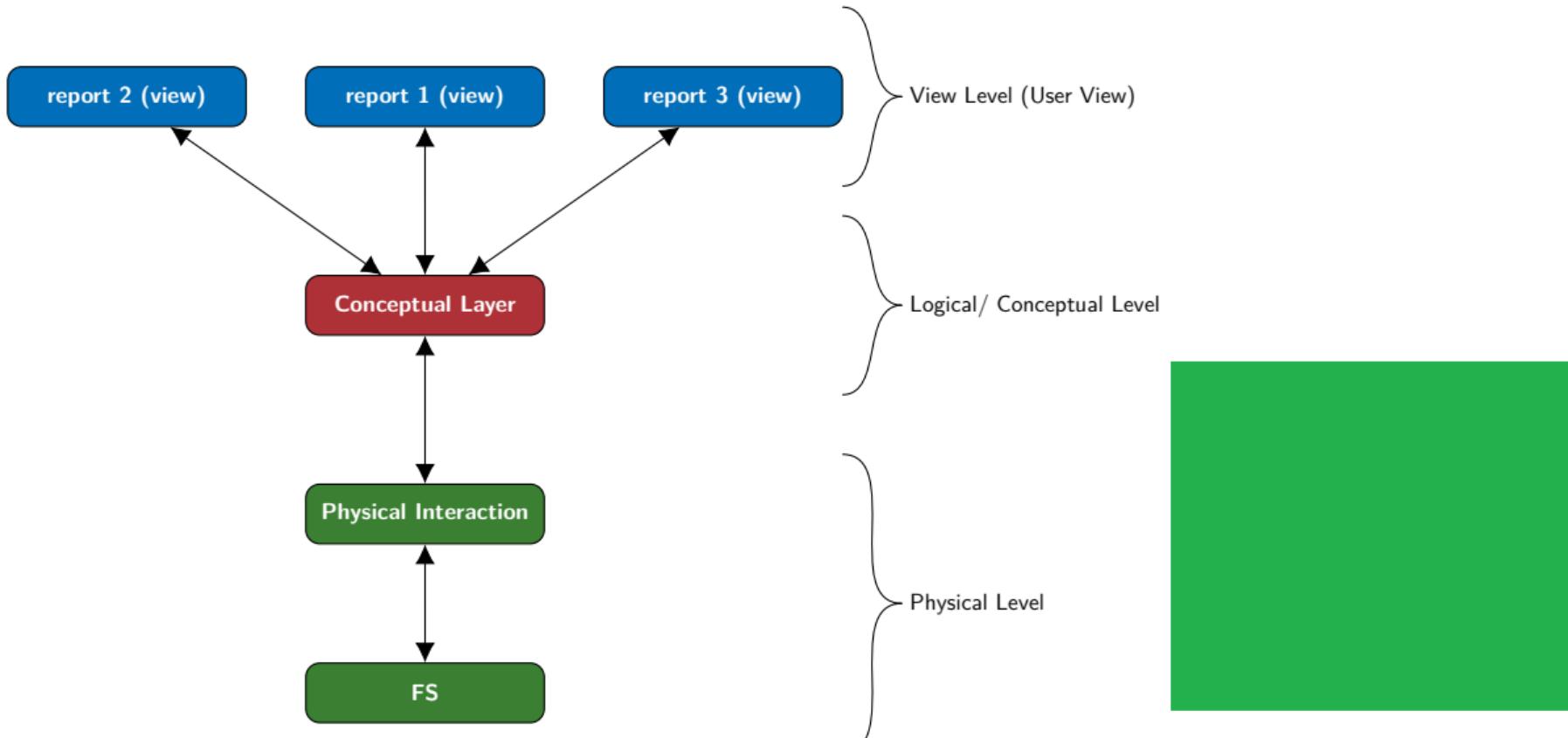
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 - Using a new storage device.



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- Describes the data structure.
- It allows you to modify the lowest level (Physical part) without any change in the logical schema. These changes could be
 - Using a new storage device.
 - Change the structure of the data used for storage.

Physical level

- **Physical level (Internal):**

- Lowest level.
- Describes how data is stored.
- Describes the data structure.
- It allows you to modify the lowest level (Physical part) without any change in the logical schema. These changes could be
 - Using a new storage device.
 - Change the structure of the data used for storage.
 - Change the file type or use different storage structures.

Physical level

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- It allows you to modify the lowest level (Physical part) without any change in the logical schema. These changes could be
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 - Change the file type or use different storage structures.
 - Changing the access method.

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 - Changing the access method.
 - Modifying indexes.

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 - Change the structure of the data used for storage.
 - Change the file type or use different storage structures.
 - Changing the access method.
 - Modifying indexes.
 - Change the compression algorithm or hashing technique.

Physical level

Example

- Database contains product information.

Physical level

Example

- Database contains product information.
- Physical layer describes

Physical level

Example

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- Physical layer describes
 - Storage mechanism and the blocks (bytes, gigabytes, terabytes etc.).

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- Database contains product information.
- Physical layer describes
 - Storage mechanism and the blocks (bytes, gigabytes, terabytes etc.).
 - The amount of memory used.

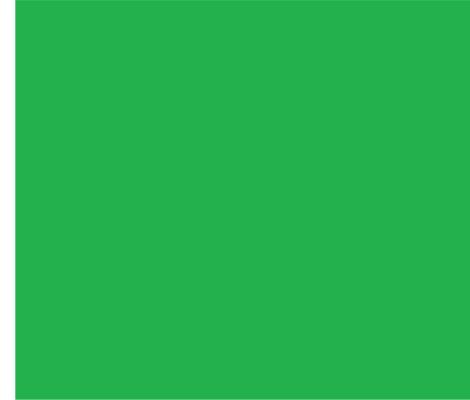
Physical level

Example

- Database contains product information.
- Physical layer describes
 - Storage mechanism and the blocks (bytes, gigabytes, terabytes etc.).
 - The amount of memory used.
 - Usually this layer abstracted from the programmers.

Logical level

- **Logical level (Conceptual):**



Logical level

- **Logical level (Conceptual):**
 - Intermediate level.



Logical level

- **Logical level (Conceptual):**
 - Intermediate level.
 - Describes what data is stored.



Logical level

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- Describes what data is stored.
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 - Change attribute (Add, delete) to existing table.

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Logical level

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Logical level

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- Database contains product information.
- Logical Layer describes
 - The product fields and their data types.
 - How this product interact with other entities in the database.
 - The programmers design this level based on the business knowledge and the requirements.

View level

- **View level (External):**



View level

- **View level (External):**
 - Highest level.



View level

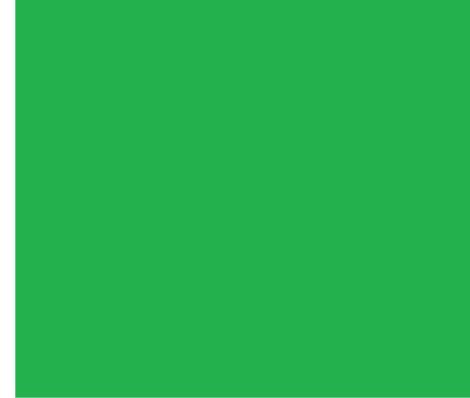
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 - Highest level.
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- Designed for category of users needs.
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- It could be extended or hidden based on user's role.
- Not all the views is extended to all users and there is an authentication based on the category.



Example

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Example

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- It could be designed to show the sales of product in specific region.

Example

- Database contains product information.
- It could be designed to show the sales of product in specific region.
- We might hide information about some products based on the teams or users.

Data solution thinking (Summary)

Let's answer our previous the question, How can we solve data challenges?



Data solution thinking (Summary)

- Let's split the problem based on the data layers.

Data solution thinking (Summary)

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 - View layer



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Data solution thinking (Summary)

- Let's split the problem based on the data layers.
 - View layer
 - When we need to add/remove/create new reports it is usually view layer.
 - We don't need to change the logical or physical layer to support the view layer.

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Data solution thinking (Summary)

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 - Logical Layer



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 - When you have missing sources into your logical layer and you need to add this source and its structure.
 - There is a performance issue in the existing reports and you need to change in the model. For example, reduce the join by creating new join table (*materialized view*).
 - Update the data type or the existing relation which could help to fix some data or performance issues.

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 - If we need to change your storage/compression/structure/access technique.
 - If we need to change the data orientation structure from row to column or key-value storage, It is time to change the physical layer.

Introduction to DWH

Motivation to Data Warehouse (DWH)

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- There are some challenges facing the people who work on data management backend:
 - Performance.
 - Integration.
 - Applying analytical functions.
- Vendors who are working to solve the above challenges creating their own product of DWH and their ultimate work is to optimize the above points.

Motivation to Data Warehouse (DWH)

Definition (What is Data Warehousing?)

A DWH is defined as a technique for collecting and managing data from varied sources to **provide meaningful business insights**. It is a blend of technologies and components which aids the strategic use of data.

The real concept was given by Inmon Bill. He was considered as a father of the DWH. He had written about a variety of topics for building, usage, and maintenance of the warehouse & the Corporate Information Factory

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- The DWH is the core of the BI system which is built for data analysis and reporting.

Motivation to Data Warehouse

Data warehouse system is also known by the following names:

- Decision Support System (DSS).
- Business Intelligence Solution.
- Executive Information System.
- Management Information System.
- Analytic Application.
- Data Warehouse.

Differences Between DWH and Operational DB

DWH vs Operational databases

Metric	Transactions DB	DWH
Volume	GB/TB	TB/PB
Historical rows	Short-term <1000M	Long-Term 1000M>
Orientation	Product	Subject or multi products
Business Units	Product team	Multi organizational units
Normalization	Normalized	Not required (De-normalized in many use cases)
Data Model	Relational	Star Schema or Multi-dim
Intelligence	Reporting	Advanced reporting and Machine Learning
Use cases	Online transactions & operations	Centralized storage (360°)

Transnational DB Use cases



Transnational DB Use cases



DWH Use cases



DWH Use cases



DWH Use cases



Types of DWH

Motivation to Data Warehouse

Types of Data Warehouse

Enterprise Data Warehouse (EDWH) It provides decision support service across the enterprise. It offers a unified approach for organizing and representing data (DWH Model). It offers data classifications according to the subject with privileges policy.

Operational Data Store (ODS): is a central database that provides an up-to-date (real-time) data from multiple transnational systems for operational reporting into a single DWH.

Data Mart: A data mart is a subset of the data warehouse. It specially designed for a particular line of business, such as sales, finance, sales or finance. In an independent data mart, data can collect directly from sources.

DWH vs ODS vs Data Mart

Metric	DWH	ODS	Data Mart
Latency	Day -1	Real-time	Day -1
Data level	Transnational	Transnational	Summary
Historical	Long-term	Snapshot	Aggregated Long-Term
Size	TB/PB	GB	GB/TB
Orientation	Multi sources	Multi sources	Product
Business Units	Multi organizational units	Product team	Business team

Use Cases of Operational DB vs DWH

Use case (Operational DB)

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 - CRM team can report their sales and customer activities from their database.
 - Product owner can take a decision based on their system backend reports.

Use case (DWH)

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- So, they need to ingest (transfer) the data from the source systems to one single database.
- The decision from the DWH is a **global and strategical decision**.
- If the company needs to build a machine learning model which needs data from different sources. They need to load the data from a centralized database rather than read each source alone.

Use case (DWH)

The Full picture required a DWH. However, we still need the other operational databases for product development perspective.

Use case (ODS)

- Why do we need the ODS?



Use case (ODS)

- Why do we need the ODS?
- How does it fit in our system?



Use case (ODS)

XTec has a call center system which handles the customer inquiries.

This system requires some data related to usage, customer information, billing details to be calculated and accumulated in **real-time** to be able to give the customer the right answer for his inquiries.

Use case (ODS)

- So, What is the challenge for this system?



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Use case (ODS)

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 - It needs specific information from different source systems.
 - It requires to track the source system database changes or update in real-time.
 - Its functionality is based on the aggregate data not the transactions for example (It needs the total outgoing calls till time or it needs the total charging amounts from prepaid or the available limits from billing if it is postpaid).

Use case (ODS)

- ODS is based on change data capture (CDC). This approach used to determine the data change and apply action based on this change.



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- ODS is based on change data capture (CDC). This approach used to determine the data change and apply action based on this change.
- ODS uses the real-time aggregations to support the online systems from different source systems.

DWH Characteristics



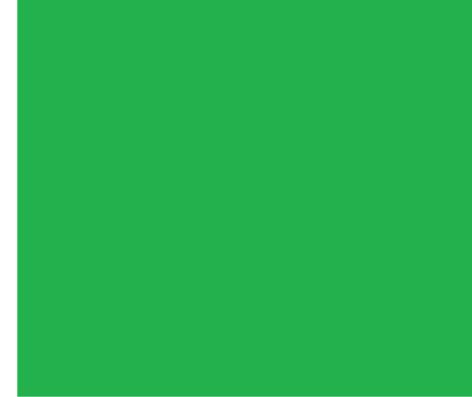
DWH Characteristics

some details about hot vs cold storage,



Datawarehouse Components

ETL Process



ETL vs ELT When? Why?

Data Models

What is data model?

Data model is

- An abstract model that organizes elements of data.



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- It describes how application (report) API data manipulation.
- It describes the conceptual design of a business or an application with its flow, logic, semantic information (rules), and how things are done.
- It refers to a set of concepts used in defining such as entities, attributes, relations, or tables.

What is data model?

Data model is not

- a science.
- a static design for each organization.
- a type of database.
- a new invention which needs to be done for each project.

Data model is

- an engineering design practices.
- a general concepts which lead to build full architecture.
- different based on the use case and the database type.
- customizable and we can utilize some of ready built architecture.
- implementing using different ways.
- affecting the information reporting performance and ways.

Why does data models are important?

- Data models are currently affecting software design.
- It decides how engineers will think about the problem they are solving.

Data Model Design

Data Model Design vs Implementation

- You need to build a home. So, how do we design this home?



Data Model Design vs Implementation

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 - Determine if the home is one level or multi-level and decide man bedrooms and bathrooms for each floor. (User needs)

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 - Decide the decorations, colors for each room, carpets, etc.
- What do we do for the implementation?
 - Hire a contractor to build (implement the design) the home.
 - This phase will implement the design but it also include some detail related to the actual way to build the tools and the material.
(Physical Design)

DWH Architecture Overview



DWH Architecture Overview

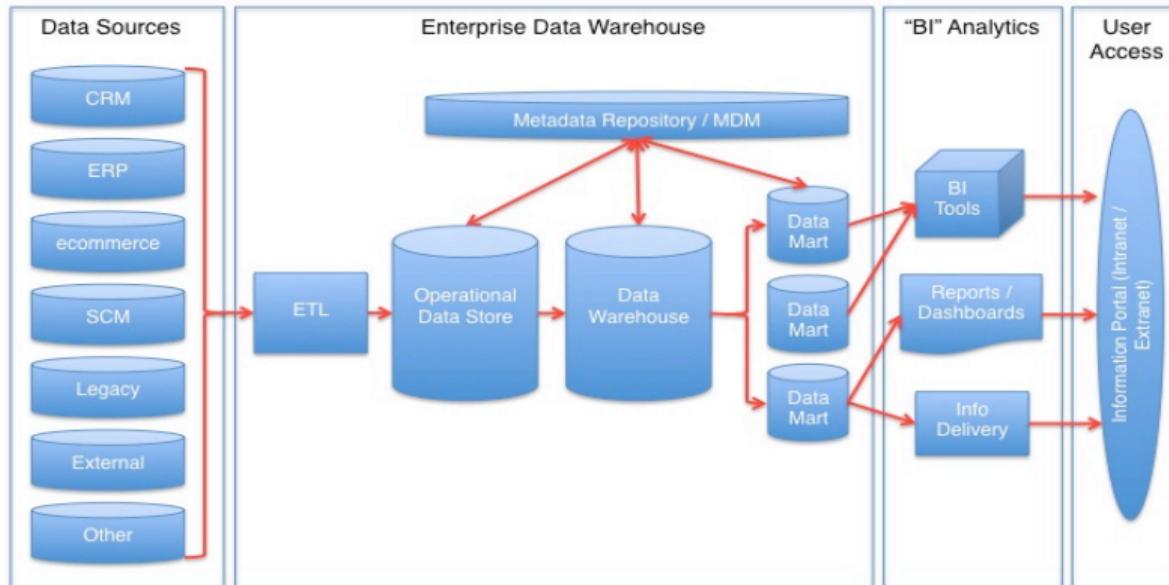


Figure: taken from XXXX

DWH Architecture Overview

There are mainly three types of Datawarehouse Architectures: -

- Single-tier architecture.
- Two-tier architecture.
- Three-tier architecture.



Cold storage vs Hot storage

some details about hot vs cold storage,



Data Encoding and Formats

Data Models

- Any Big Data solution working based distributed systems.



Data Models

- Any Big Data solution working based distributed systems.
- What is distributed systems in brief?



Further Readings and Assignment

Introduction To Distributed Systems

Chapter Objectives

- Understand the distributed systems concepts.



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Further Readings and Assignment

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Storage

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YARN

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Hadoop I/O

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Processing

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Map-Reduce

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Map-Reduce Components

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Map-Reduce Components

- Any Big Data solution working based distributed systems.
- What is distributed systems in brief?



Word-Count Example

Word-Count Example

- Any Big Data solution working based distributed systems.



Word-Count Example

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Pig

- Any Big Data solution working based distributed systems.



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Hive

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- What is distributed systems in brief?



ZooKeeper

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Further Readings and Assignment

Functional Programming

Why functional programming commonly used in distributed systems?

Introduction to Scala



Further Readings and Assignment

Spark Framework

Spark Philosophy towards the Engine and the Programming languages

Spark Framework: Spark Philosophy towards the Engine and the Programming languages

- Any Big Data solution working based distributed systems.



Spark Framework: Spark Philosophy towards the Engine and the Programming languages

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Spark Basics

Spark Framework: Spark Basics

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Spark Framework: Spark Basics

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Spark Basics

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Spark Programming using RDDs

Spark RDD

Spark Programming using RDDs

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Spark Programming using RDDs

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- What is distributed systems in brief?



Spark Working With Key/Value Pairs

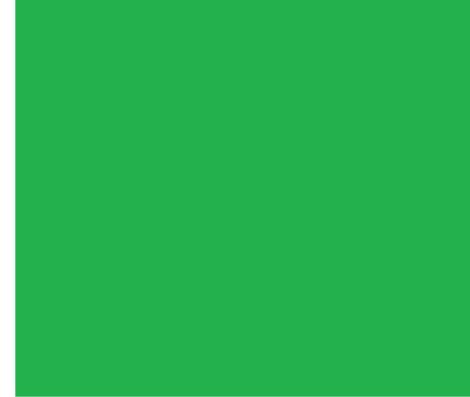
Spark Programming using RDDs

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Spark Programming using RDDs

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Spark Programming using RDDs

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Spark Datasets/Dataframe

Spark Datasets/Dataframe

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Spark Datasets/Dataframe

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Spark SQL

Spark Datasets/Dataframe

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Spark Datasets/Dataframe

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Dataframes/Datasets vs. RDDs

Spark Datasets/Dataframe

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Spark Datasets/Dataframe

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Spark on Production

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Spark on Production

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Spark For Batch Processing

Spark For Batch Processing

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Spark For Batch Processing

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Building custom input and output connector using Spark

Building custom input and output connector using Spark

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Building custom input and output connector using Spark

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Spark Streaming

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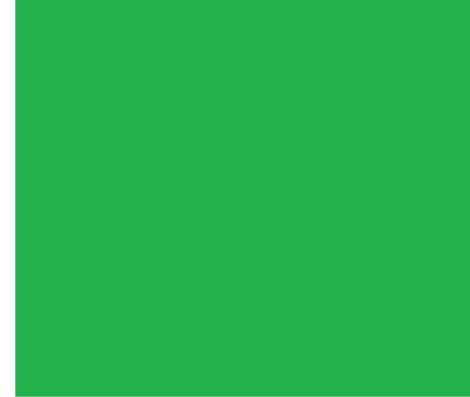


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Spark using other Programming Languages

PySpsark for Python Geeks

Spark using other Programming Languages

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Spark using other Programming Languages

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Spark using other Programming Languages

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RSpark for R Geeks

Spark using other Programming Languages

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Spark using other Programming Languages

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Spark For Data Scientist

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Spark For Data Scientist

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Spark Graph Dataframe/Graphx

Spark Graph Dataframe/Graphx

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Spark Graph Dataframe/Graphx

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Spark Graph Dataframe/Graphx

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Tuning your Spark Jobs

Tuning your Spark Jobs

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Tuning your Spark Jobs

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Tuning your Spark Jobs

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Further Readings and Assignment

Real World Applications

Big Data Development Life Cycle

Template Concept for Data Engineering

Template for ETL Application

Template for QA

Template for Streaming Applications

Template for Machine Learning Applications

Further Readings and Assignment

Massaging Systems

Motivation

Massaging Systems Architecture

JMS as an example

Introduction to Kafka

Kafka Architecture



Kafka Topics

Partitions



Kafka Producers

Kafka Consumers



Kafka Connector

Kafka Custom Connectors

Kafka Configuration

Kafka Configuration Optimizations

Kafka Operations

Kafka Integration with Enterprise tools

Further Readings and Assignment

Data Orchestration



Motivation

Enterprise vs Open source tools

Open source tools (Oozie as an Example)

Enterprise source tools

How to choose the right tool?

Further Readings and Assignment

NOSQL

Introduction to NoSQL Databases.

Cassandra



Why Cassandra?

Introducing Cassandra

The Cassandra Data Model

Architecture

Reading and Writing Data

Integrating Hadoop

Further Readings and Assignment

Elastic



Further Readings and Assignment

Data Architecture Design

Further Readings and Assignment

Appendix

Appendix A- Shell Programming

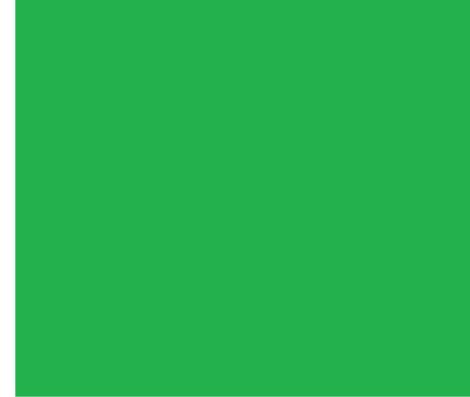
Appendix A- Shell Programming

- Any Big Data solution working based distributed systems.



Appendix A- Shell Programming

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Appendix B- Java Programming

Appendix B- Java Programming

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Appendix B- Java Programming

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Appendix C- Scala Programming

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Appendix C- Scala Programming

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Appendix D- SQL Programming

Appendix D- SQL Programming

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Appendix D- SQL Programming

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Appendix E- Oozie Orchestration

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Appendix F- DWH Concepts and Data Modeling Design

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Appendix G- Machine Learning Concepts Data Engineers

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Appendix H- Docker for Data Engineers

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