**People's Democratic Republic of Algeria**
**Ministry of Higher Education and Scientific Research**
University IBN KHALDOUN – TIARET

# Dissertation

Presented to:

FACULTY OF MATHEMATICS AND COMPUTER SCIENCE
DEPARTMENT OF COMPUTER SCIENCE

In partial fulfilment of the requirements for the **Master**'s degree
Specialty: Fixed and mobile network and telecommunications
With the aim of creating a start-up:

**HealthGrid Solutions**

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**On the subject:**

# Parallel and Distributed System for Medical Data Processing

Defended publicly on 11/06/2024 in Tiaret in front the jury composed of:

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2023-2024

# Remerciements

**« Louange à Allah qui nous a guidés à ceci. Nous n'aurions pas été guidés, si Allah ne nous avait pas guidés ».**

[Sourate 7. Al Araf verset 43]

Je tiens à exprimer mes plus vifs remerciements à **Monsieur DJAFRI Laouni** pour avoir accepté de présider le jury.

Ma reconnaissance, et mes sincères remerciements vont à **Monsieur MERATI Medjeded** pour m'avoir dirigé tout au long de la réalisation de ce travail. Ses orientations, ses encouragements, sa compréhension, sa disponibilité constante m'ont été d'une précieuse aide.

Je tiens à remercier également **Monsieur Monsieur KHERICI Cheikh** pour avoir accepté d'examiner ce travail et l'enrichir par ses propositions.

Enfin, mes sincères remerciements et respects vont aux enseignants qui m'ont enseigné et qui, par leurs compétences, m'ont soutenu dans la poursuite de mes études.

# Dédicaces

**بسم الله الواحد الأحد، الفرد الصمد، الذي لم يلد ولم يولد، ولم يكن له كفواً أحد. أهدي هذا العمل**

**إلى كل من ساهم في دعمي وإلهامي، إلى أسرتي العزيزة التي كانت دائماً سندي وملاذي، وإلى أصدقائي الأوفياء الذين لم يبخلوا عليّ بالتشجيع والمساندة. شكراً لكم جميعاً من القلب**

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# General Introduction

In an international characterised by way of speedy technological advancements, the effective use of clinical records has become essential for improving healthcare outcomes and scientific choice making. The development of records and communique technologies (ICT) has opened new horizons in the field, enabling the gathering, garage, and analysis of massive medical statistics units. However, processing this statistics poses considerable challenges due to its titanic quantity, variability, and touchy nature.

This thesis explores the intersection of Big Data and healthcare, focusing on the deployment of allotted processing structures to manage and analyse medical data efficiently. The first bankruptcy presents an in-intensity look at the characteristics and significance of Big Data in the healthcare area. It examines the particular demanding situations posed via medical facts and the criminal frameworks that govern its use.

The second bankruptcy delves into disbursed processing structures, highlighting their function in addressing the complexities of medical records processing. It discusses various frameworks and technologies that facilitate the efficient coping with of large datasets, with a selected emphasis on their software in healthcare.

The third bankruptcy is dedicated to Apache Spark, an effective device for Big Data processing. It outlines the key features and advantages of Spark, illustrating its talents via realistic use instances in the scientific field. The bankruptcy also covers the mixing of Spark with different statistics processing gear to enhance its capability and efficiency.

Finally, the fourth chapter makes a speciality of the development and deployment of a healthcare records processing gadget using the ideas and technology discussed in the preceding chapters. It consists of a complete case observe that demonstrates the sensible utility of the proposed gadget in an actual-world healthcare placing.

By bridging the space between theoretical knowledge and realistic implementation, this thesis goals to contribute to the continuing efforts to harness the strength of Big Data in healthcare, ultimately main to better affected person consequences and extra informed medical choices.

## Background and motivation

The healthcare area is currently facing an exponential boom of facts from various sources together with electronic clinical statistics, connected medical devices, scientific imaging, genomic data, and many others. This abundance of facts offers significant ability to improve healthcare, scientific research, and useful resource control. However, it also poses foremost challenges in terms of accumulating, storing, analysing, and managing this massive statistics.

The imperative to leverage this statistics to make informed medical choices, improve diagnostics, personalize remedies, and expect fitness traits has emerge as a priority within the healthcare area. Healthcare institutions, researchers, and clinical generation groups are actively looking for revolutionary solutions to make the most this information efficaciously and ethically.

In this context, parallel and distributed systems offer a promising manner to meet the growing wishes of medical records processing. By dispensing processing tasks across more than one computing nodes, those systems permit green control of big facts volumes, boost up analyses, and facilitate actual-time get admission to applicable statistics. Moreover, they provide horizontal scalability, permitting to cope with the non-stop expansion of information volume.

The underlying motivation for this studies challenge lies inside the desire to suggest a modern and scalable answer for medical statistics processing. By exploring the possibilities provided by way of parallel and distributed structures, we intention to make a contribution to enhancing healthcare by means of allowing greater efficient and faster exploitation of scientific information even as ensuring its security and confidentiality.

This venture is a part of a broader initiative geared toward encouraging technological innovation in healthcare and starting new possibilities for scientific studies and patient care. By presenting a robust and scalable platform for medical records processing, our purpose is to facilitate medical advancements, enhance diagnostics and treatments, and ultimately contribute to the health and nicely being of individuals.-[1]

# Chapter I Medical data

## Introduction

In the area of healthcare, scientific facts performs a pivotal position in driving knowledgeable scientific decisions, improving patient results, and advancing clinical research. This bankruptcy delves into the multifaceted nature of scientific records, exploring its various types, traits, and the extensive challenges related to its processing. The recognition may be on the precise complexities of scientific statistics, including its volume, variability, and sensitivity, and how these elements have an impact on the processes to records management and analysis in healthcare settings.

## I-1 Medical data

This thesis objective is to give a parallel and allotted machine for processing scientific records. This gadget seeks to cope with the following demanding situations:

a) **Performance:** Accelerate the processing of scientific information to obtain effects inside affordable periods.
b) **Scalability:** Efficiently control the growing volume of medical information.
c) **Security**: Ensure the confidentiality and security of medical statistics.

### I-1-1 Definition of medical data

Medical information refers to personal statistics concerning the physical or intellectual health of a character, beyond, gift, or future (which includes the supply of healthcare offerings) that famous data approximately the man or woman's health.

### I-1-2 Types of medical data

a) **Clinical data:** Includes patient statistics, which includes scientific outcomes, physical examination findings, medicinal drug prescriptions, and so forth.
b) **Medical imaging data:** Includes X-rays, CT scans, MRIs, and greater.
c) **Laboratory data:** Includes consequences from blood tests, urine tests, and many others.
d) **Genomic data:** Includes facts about sufferers' DNA.
e) **Public health data:** Includes records on population health, together with delivery and mortality rates, sickness data, and so forth.

### I-1-3 Characteristics of medical data

a) **Volume:** Medical facts is regularly massive and complex. An unmarried electronic medical document can include loads of pages of textual content, snap shots, and videos.
b) **Variety:** Medical statistics comes from various sources and in one-of-a-kind codecs. It may be structured, semi-based, or unstructured.
c) **Velocity:** Medical statistics is continuously generated and need to be processed in real time. Data from patients in intensive care, as an example, should be constantly analysed to detect symptoms of fitness deterioration.

## I-2 Issues and challenges in processing medical data with distributed systems

The specific legal framework for health information is crucial since it involves multiple sectors. According to a parliamentary report on AI, "the development of AI is anticipated to profoundly transform the practices of healthcare specialists: diagnostic help and assist for remedy improvement, ongoing patient monitoring..."

These new practices rely on the exploitation of fitness databases. According to the aforementioned report from the National Assembly, "enforcing AI-based totally diagnostics would require databases to educate those algorithms."

**a) Confidentiality and data security**: Medical data is touchy and ought to be protected against unauthorized get admission to and cyber-attacks. Distributed structures can divulge information to an extra variety of risks, as statistics is stored and processed on a couple of computers.

**b) Interoperability:** Medical statistics processing structures should engage with unique fitness information structures. Distributed structures can make interoperability extra tough, as one of kind, systems may also use exclusive statistics codecs and conversation protocols.

**c) Possible solutions:**

- Implement rigorous security features to protect scientific records. This includes statistics encryption, access manipulate, and intrusion detection. [2]
- Use distributed facts processing technologies that make sure statistics exceptional. This includes facts replication and data validation.
- Develop interoperability requirements for scientific records processing systems. This will facilitate communication between different systems and the seamless trade of records.
- Establish effective information governance. This consists of developing rules and strategies for managing medical information and appointing a statistics governance officer**.**
- Optimize allotted structures to enhance performance and scalability. This involves deciding on the right machine architecture and accurately sizing resources.
- Implement redundancy mechanisms to make certain system availability. This includes facts duplication and setting up backup systems. [3]

## I-3 Big data in healthcare

### I-3-1 Definition and importance of big Data in healthcare

"Big Data" refers to big and complicated statistics sets that cannot be processed via conventional facts control and analysis equipment. In healthcare, Big Data features a wide variety of scientific data from numerous resources, which include digital fitness records (EHRs), patient tracking devices, genomic databases, and cell fitness programs.

## I-3-2 Sources of big Data in healthcare

**a) Electronic health records:** Clinical data recorded with the aid of healthcare specialists.

**b)** Patient Monitoring Devices: Real-time facts on patients' crucial symptoms and sports.

**c) Genomic data**: DNA sequences and genetic statistics.

**d) Mobile health applications**: Data accrued thru fitness and wellbeing monitoring apps.

**e) Data**: Information from scientific trials and clinical research. [4]

## I-3-3 Benefits of using big data in healthcare

**a) Improved patient care:** Analysing records to personalize and enhance treatments.

**b) Early disease detection:** Identifying early symptoms thru predictive fashions

**c) Operational efficiency:** Optimizing medical and administrative tactics.

**d) Research and innovation**: Advancing knowledge of diseases and developing new treatments.

**e) Public health management:** Monitoring and coping with epidemics and persistent diseases at scale.

**f) Volume**: Enormous amounts of statistics generated every day.

**g) Variety**: Diverse forms of statistics (based, semi-dependent, unstructured).

**h) Velocity:** Speed at which data is generated and wishes to be processed.

**i) Veracity**: Reliability and exceptional of data.

**j) Value**: Potential to transform healthcare thru records evaluation.

## I-4 Challenges associated with big data in healthcare

**a) Data privacy and security:** Protecting sensitive affected person statistics.

**b) Integration and interoperability**: Merging information from one of a kind assets and systems.

**c) Data quality:** Ensuring the accuracy and completeness of amassed information.

**d) Technical expertise:** Need for experts in facts analysis and health informatics.

**e) Regulation and compliance:** Adhering to present day standards and policies (e.g., GDPR).

## I-4-1 Use cases of big data in healthcare

**a) Predictive analytics:** Using algorithms to forecast fitness traits and outcomes.

**b) Personalized medicine**: Tailoring treatments based totally on genetic and character patient records.

**c) Epidemiological surveillance:** Tracking and reading disorder traits to prevent outbreaks.

**d) Health resource management:** Optimizing useful resource allocation and workflow management in hospitals. [5]

## I-5 Ethical considerations in medical data processing privacy and confidentiality

a) **Patient consent:** Obtaining informed consent from patients before amassing and using their clinical facts is fundamental. Patients have to be privy to how their data might be used, saved, and shared.
b) **Data anonymization:** Ensuring that personal identifiers are eliminated from data sets to protect affected person privacy even as allowing data for use for studies and analysis.
c) **Secure data storage:** Implementing strong safety features to defend information from unauthorized get right of entry to, breaches, and leaks.

### I-5-1 Data ownership and control

a) **Patient rights:** Patients have to have the right to access their personal medical data and manipulate who can use it and for what purposes.
b) **Transparency**: Healthcare providers and researchers ought to be obvious about information series practices and how facts can be used.
c) **Ethical use of data**: Ensuring that scientific information is used entirely for valid scientific, research, and healthcare development functions.

### I-5-2 Bias and fairness

a) **Avoiding discrimination:** Ensuring that information evaluation does no longer cause biased or discriminatory practices. Algorithms and models ought to be designed and tested to be truthful and impartial.
b) **Inclusivity**: Including diverse populations in records units to avoid skewed outcomes and ensure that findings are relevant to all segments of the population.
c) **Equitable access**: Ensuring that improvements in information-driven healthcare benefit all patients similarly, irrespective of socioeconomic fame or geographical region.

### I-5-3 Accountability and responsibility

a) **Ethical governance:** Establishing oversight committees to display and put into effect ethical requirements in clinical information processing.
b) **Professional responsibility:** Healthcare specialists and information scientists need to adhere to ethical pointers and pleasant practices in their paintings.
c) **Regulatory compliance:** Ensuring compliance with laws and rules governing clinical records, which include GDPR, HIPAA, and different applicable legislation.

### I-5-4 Potential risks and mitigation

a) **Data misuse:** Preventing the use of clinical facts for non-healthcare functions, including business exploitation or surveillance.
b) **Error and harm:** Implementing strict fine manage measures to minimize mistakes in statistics processing that might cause incorrect diagnoses or remedies.
c) **Patient harm:** Safeguarding against any moves or choices based totally on facts evaluation that would cause damage to patients.

### I-5-5 Ethical frameworks and guidelines

a) **Principles of bioethics**: Applying the principles of bioethics-autonomy, beneficence, non-maleficence, and justice—to facts processing sports.
b) **Institutional review boards (IRBs):** Using IRBs to study and approve studies regarding medical information to make sure moral requirements are met.
c) **Codes of conduct:** Developing and adhering to codes of behaviour and ethical tips precise to scientific data processing and studies.

## I-6 Impact of data quality on medical decision making

a) **Accuracy**: The degree to which statistics effectively reflects the real-global entities it represents. Accurate information is important for dependable medical decisions.
b) **Completeness:** Ensuring that each one important statistics is present. Incomplete records can result in misinformed decisions and neglected diagnoses.
c) **Consistency**: Data should be constant throughout extraordinary resources and through the years. Inconsistent facts can create confusion and cause errors in affected person care.
d) **Timeliness**: Data have to be up to date. Outdated records can result in decisions primarily based on out of date facts, affecting the exceptional of care.
e) **Relevance**: Data have to be applicable to the choice-making method. Irrelevant facts can clutter evaluation and distract from critical statistics.

### I-6-1 Impact on diagnosis

a) **Accurate diagnoses:** High-high-quality facts enables specific identity of medical situations. Misdiagnoses are frequently related to facts inaccuracies.
b) **Differential diagnosis**: Comprehensive and correct statistics helps the technique of differential analysis, in which more than one capability conditions are taken into consideration.
c) **Diagnostic delays:** Poor facts first-class can put off diagnosis, extend affected person suffering, and boom healthcare expenses.

### I-6-2 Impact on treatment plans

a) **Personalized treatment**: High-first-rate statistics helps personalized remedy plans tailor-made to individual patient needs, improving treatment efficacy.
b) **Treatment efficacy**: Accurate and whole facts guarantees that remedies are based at the high quality to be had evidence, growing the chance of a hit outcomes.
c) **Medication errors**: Inaccurate information regarding affected person history, hypersensitive reactions, and modern-day medicines can lead to harmful remedy errors.

### I-6-3 Impact on patient outcomes

a) **Improved outcomes**: Reliable information contributes to better fitness consequences by using informing accurate diagnoses and powerful treatments.
b) **Patient safety**: High records quality reduces the chance of clinical errors, thereby enhancing patient protection.
c) **Monitoring and follow-up:** Accurate facts is essential for powerful monitoring and comply with-up, ensuring that patients acquire ongoing care as wanted.

### I-6-4 Challenges and solutions

a) **Data entry errors:** Manual data entry can introduce errors.
b) Implementing computerized statistics capture and validation structures can mitigate this hazard.
c) **Interoperability**: Lack of standardization throughout structures can result in inconsistencies. Adopting well-known standards for statistics change can beautify consistency.
d) **Data integration**: Integrating records from a couple of assets can be hard. Utilizing superior information integration tools and techniques can enhance statistics completeness and consistency.
e) **Training and education:** Ensuring that healthcare specialists are trained in accurate data access and control practices is critical.

### I-6-5 Best practices for ensuring data quality

a) **Data governance**: Establishing a sturdy records governance framework to supervise records high-quality management.
b) **Regular audits**: Conducting normal audits to discover and correct information high-quality problems.
c) **Real-time data quality monitoring:** Implementing actual-time monitoring gear to locate and rectify statistics high-quality problems as they get up.
d) **Patient involvement**: Engaging sufferers in the verification of their data can assist make sure accuracy and completeness.

## I-7 Breast cancer: definition, diagnosis, and differences between malignant and benign tumors

Breast most cancers is one of the most commonplace styles of cancer amongst women international. It develops when ordinary cells multiply uncontrollably in the breast tissues. To higher recognize this disorder; let us have a look at its definition, diagnostic techniques, and the differences among malignant and benign tumors.

**a) Definition of breast cancer:** Breast most cancers is a malignant tumor that forms in the cells of the breast. This strange increase can start in one-of-a-kind types of breast tissues, along with the ducts that bring milk to the nipple (ductal carcinoma) or the glands that produce milk (lobular carcinoma). Risk elements consist of a circle of relative records of breast most cancers, a BRCA1 or BRCA2 genetic mutation, estrogen publicity, weight problems, and different environmental elements.

**b) Diagnosis of breast cancer:** Mammography is one of the most not unusual equipment for detecting breast most cancers. It is an X-ray of the breast which could discover abnormalities before they may be palpable. When a mammogram shows suspicious results, other assessments are commonly wished. These may additionally consist of a breast ultrasound, MRI (Magnetic Resonance Imaging), or a biopsy, wherein a tissue pattern is taken for examination beneath a microscope.

**c) Differences between malignant and benign tumors:** Benign and malignant tumors range of their conduct and appearance underneath a microscope:

- **Benign tumors:** These tumors do now not unfold to different parts of the frame and aren't life-threatening. They tend to be properly-defined and are often surrounded by means of a tablet of tissue. Examples include cysts or fibroadenomas.
- **Malignant tumors:** Malignant tumors, or cancers, have invasive and metastatic ability, meaning they are able to invade surrounding tissues and unfold to different components of the body. Under a microscope, cancer cells often show disorganized boom and odd nuclei. Examples include invasive ductal carcinoma and invasive lobular carcinoma.

## Conclusion

The pleasant of medical records has a direct and profound impact on clinical selection-making. Ensuring excessive statistics great is vital for correct diagnoses, effective treatments, and ideal affected person results. By addressing facts great troubles through complete strategies and pleasant practices, healthcare companies can appreciably decorate the reliability and effectiveness of medical selections. [6]

# Chapter II Distributed systems

## Introduction

Distributed systems have revolutionized information processing via permitting the dealing with of huge quantities of records throughout a couple of nodes. This bankruptcy explores the essential concepts of allotted systems, their architecture, and their applicability in the scientific field. The benefits and downsides of using distributed structures, especially inside the context of scientific records, could be examined, imparting a complete information of the way those structures can enhance data processing talents in healthcare.

## II-1 Definition of distributed systems

A disbursed machine is a collection of laptop packages that make use of computing resources throughout multiple awesome computing nodes to achieve a common and shared objective. Distributed structures intention to eliminate bottlenecks or primary points of failure inside a machine.

Also known as allotted computing or allotted databases, these systems depend upon wonderful nodes to perform communique and synchronization over a not unusual network. These nodes usually represent awesome bodily hardware gadgets but also can represent distinct software strategies or other recursive encapsulated systems. The primary purpose of disbursed systems is to remove bottlenecks or principal factors of failure.

## II-2 Distributed computing structures exhibit the following characteristics

**a) Resource sharing:** A distributed machine can share hardware, software program, or statistics sources.

**b) Concurrent processing**: Multiple machines can manner the identical characteristic simultaneously.

**c) Scalability:** The computing and processing capacity can be scaled in step with desires via including extra machines.

**d) Error detection**: Failures may be detected more without problems.

**e) Transparency:** A node can get entry to and communicate with other nodes inside the system seamlessly.

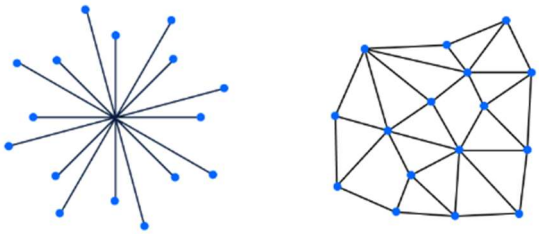


*Figure 1: Centralized*

## II-3 Architecture of distributed systems

There are many types of distributed structures. The maximum commonplace ones are as follows:

**a) Client-server:** A patron-server structure divides duties into two major elements. The customer is liable for presenting the consumer interface, which then connects to the server through the community. The server is answerable for dealing with enterprise logic and states. A customer-server architecture can easily end up a centralized architecture if the server isn't always redundant. A absolutely allotted purchaser-server configuration could have multiple server nodes to distribute consumer connections. Most modern customer-server architectures contain clients connecting to a disbursed gadget encapsulated on the server. [7]

**b) Multi-tier:** A multi-tier structure extends the customer-server structure. In a multi-tier architecture, the server breaks down into additional granular nodes that decouple additional server responsibilities, which include processing and records control. These extra nodes are used to asynchronously handle lengthy-strolling tasks, freeing up the remaining number one nodes to recognition on responding to purchaser requests and interfacing with the facts store. [8]

**c) Peer-to-peer:** In a peer-to-peer disbursed device, each node incorporates the total instance of an application. There is not any separation of nodes among presentation and data processing. A node consists of each the presentation layer and facts management layers. Peer nodes can preserve the entire nation facts of the whole device. [9] Peer-to-peer systems have the advantage of big redundancy. When a peer-to-peer node is initialized and brought on line, it discovers and connects to other peers, then synchronizes its neighbourhood state with the machine as a whole. Due to this selection, the failure of one node in a peer-to-peer system does now not disrupt another nodes. This additionally way that a peer-to-peer gadget might be resilient. [10]

**d) Service-oriented architecture (SOA):** Service-oriented structure (SOA) is a predecessor to microservices. The main distinction among SOA and microservices lies inside the scope of nodes: the scope of microservice nodes is on the purposeful level. In microservices, a node integrates the business good judgment to address a particular set of functionalities, such as fee processing. Microservices comprise numerous disparate enterprise logic nodes that interact with unbiased database nodes. In evaluation, SOA nodes combine a whole application or business department. The service boundary for SOA nodes generally includes a whole database device inside the node. [11]. Microservices have come to be an extra famous opportunity to SOA structure due to their blessings. They are modular, permitting groups to reuse functionalities supplied by using small service nodes. They are sturdier and permit for more dynamic vertical and horizontal scaling. [12]

## II-4 Advantages and disadvantages of distributed systems inside the medical context with spark

### a) Advantages

- **Performance:** Distributed structures can system huge scientific information units quicker than centralized structures, as the processing is spread throughout multiple computer systems. Spark, specifically, is designed for instant processing of big-scale statistics.
- **Scalability:** Distributed systems can effortlessly adapt to increasing facts volumes by adding new computer systems to the system. Spark permits horizontal scaling through including extra nodes.
- **Availability:** Distributed structures may be greater to be had than centralized systems, because the failure of a unmarried computer does now not have an effect on the complete gadget. With Spark, data and approaches may be replicated across more than one nodes to ensure high availability.
- **Reliability:** Distributed structures may be greater dependable than centralized systems, as information is replicated throughout more than one computer systems. Spark affords mechanisms for fault tolerance and information replication.
- **Cost:** Distributed systems can be much less luxurious than centralized systems, as there is no want to purchase a powerful crucial computer. By using clusters of smaller, less luxurious machines, prices may be decreased.

### b) Disadvantages

- **Complexity:** Distributed structures are more complicated to layout and manipulate than centralized structures. Spark, regardless of having effective abstractions, requires a deep knowledge of allotted structure for powerful implementation.
- **Security:** Distributed structures can be greater susceptible to cyber-attacks than centralized structures, as information is spread across a couple of computers. Ensuring records protection in disbursed surroundings may be complex.
- **Confidentiality:** Medical information is touchy and have to be covered in opposition to unauthorized access. Distributed systems could make facts security and confidentiality extra tough due to the distribution of statistics throughout multiple nodes.
- **Interoperability:** Distributed systems may be extra difficult to interoperate with other fitness information structures than centralized structures. Integrating Spark with numerous scientific systems requires additional efforts to make certain compatibility.

## II-5 Distributed computing frameworks

Distributed computing frameworks are software libraries and gear that enable the improvement of allotted programs. They offer abstractions for disbursed communication, information partitioning, synchronization, and fault tolerance. Here are a few famous distributed computing frameworks:

**a) Apache hadoop**: An open-supply framework that permits for the disbursed processing of big facts units across clusters of computer systems the usage of simple programming models. It is designed to scale up from unmarried servers to hundreds of machines, each supplying neighbourhood computation and storage. [13]

**b) Apache spark**: An open-source, disbursed computing machine used for big data processing and analytics. Spark offers an interface for programming complete clusters with implicit information parallelism and fault tolerance. [14]

**c) Flink**: An open-supply flow-processing framework for high-performance, dependable, and actual-time applications. It offers robustness, high throughput, low-latency, and precisely-as soon as semantics. [15]

**d) Google's dataflow**: A unified version for batch and streaming statistics processing, with a managed service for executing such data processing jobs on Google Cloud.

**e) Apache storm**: A loose and open-source distributed actual-time computation system. Storm makes it smooth to reliably procedure unbounded streams of information, doing for real-time processing what Hadoop did for batch processing. [16]

## II-6 Comparative analysis

**a) Ease of use**: Spark has a less complicated API and it is less complicated to use in comparison to Hadoop. Flink and Storm are extra complex.

**b) Performance**: Spark and Flink provide better performance for iterative algorithms as compared to Hadoop. Dataflow's overall performance is corresponding to Spark and Flink.

**c) Fault tolerance**: All these frameworks offer fault tolerance however with distinct mechanisms. Hadoop uses replication for fault tolerance, Spark makes use of Resilient Distributed Datasets (RDDs), Flink uses a combination of replication and checkpointing, and Dataflow makes use of chronic disks.

**d) Real-time processing**: Flink, Storm, and Dataflow assist actual-time processing, while Hadoop does no longer. Spark supports close to actual-time processing.

**e) Community support**: Hadoop and Spark have huge community guide compared to Flink and Storm. Dataflow, being a Google product, has accurate help but a smaller community.

**f) Learning curve**: Hadoop has a steep getting to know curve as compared to Spark. Flink, Storm, and Dataflow also require widespread time to analyse.

## II-7 Regulatory compliance in medical data handling

Regulatory compliance in medical data managing refers to the adherence to laws, rules, pointers, and specs relevant to clinical data approaches. It is a essential component of healthcare informatics, specifically with the growing incidence of digital health records (EHRs) and big information analytics.

**a) Health insurance portability and accountability act (HIPAA):** In the United States, HIPAA units the same old for protective sensitive patient records. Any organization coping with protected health statistics (PHI) have to make sure that all the required physical, network, and process safety features are in place and accompanied. [17]

**b) General Ddata protection regulation (GDPR): I**n the European Union, GDPR imposes strict policies on controlling and processing in my opinion identifiable facts (PII). It also extends the protection of personal data and information safety rights via giving manipulate lower back to EU residents. [18]

**c) Data protection act:** In the United Kingdom, the Data Protection Act controls how corporations, companies, or the government utilizes private facts. It is aligned with the GDPR, gives strict ideas for facts coping with, and stipulates stiff penalties for non-compliance. [19]

**d) Other country-specific regulations:** Many nations have their own specific regulations for medical records dealing with. For example, Canada has the Personal Information Protection and Electronic Documents Act (PIPEDA), and Australia has the Privacy Act. [20]

Compliance with those regulations includes several key elements:

**a) Data minimization:** Only accumulate the statistics this is necessary, and keep away from gathering records "just in case."

**b) Consent**: Patients must offer informed consent for his or her records to be amassed and used.

**c) Anonymization:** Personal identifiers must be eliminated from the information to protect patient privacy.

**d) Security:** Implement sturdy security features to protect records from breaches.

**e) Access controls:** Only legal people must have get admission to to the information.

**f) Audit trails:** Keep logs of all sports concerning affected person facts to offer duty.

**g) Data quality:** Ensure the facts is correct and updated.

**h) Data retention and destruction:** Do not hold records longer than important, and cast off it securely.

## Conclusion

The exploration of dispensed systems discovered their ability to improve medical information processing by way of presenting scalability, reliability, and overall performance improvements. Despite the complexities and safety worries related to those structures, their benefits in dealing with big-scale statistics lead them to useful inside the medical subject. Future advancements and proper implementation techniques will similarly mitigate the demanding situations, making dispensed structures a cornerstone in modern-day healthcare data control.

# Chapter III Apache spark

## Introduction

Apache Spark has emerged as an effective tool for huge statistics processing, supplying robust capabilities, which are particularly useful for the healthcare enterprise. This chapter presents an in-depth study Apache Spark, its key features, and the blessings it brings to scientific records processing. Through various use cases and an instance implementation, the bankruptcy will illustrate how Spark's talents may be leveraged to decorate records processing performance and effectiveness in healthcare settings.

## III-1 Apache spark: a powerful tool for big data processing in healthcare

Apache Spark is an open-source unified facts processing framework for batch and streaming information. It offers a huge variety of functionalities to deal with massive volumes of information at excessive velocity, such as:

**a) Data transformation**: Spark helps a wealthy set of facts transformation operations, which include filtering, mapping, becoming a member of, and aggregation.
**b) Data analysis**: Spark consists of libraries for statistics evaluation, allowing advanced operations like statistical computations and exploratory data evaluation.
**c) Machine learning**: Spark permits the constructing and deployment of gadget studying fashions at scale via its MLlib library.
**d) Streaming data**: Spark can deal with actual-time data streams with Spark Streaming. [21]

Spark is written in Scala and supports multiple programming languages, which include Python, Java, and R. It can run on neighbourhood clusters, on public clouds, and on Hadoop systems.

## III-2 Features and benefits of spark for data processing

Spark gives several benefits for data processing, which includes:

**a) Performance**: Designed to be fast and green, Spark can system massive volumes of statistics at excessive pace because of its in-memory processing engine.
**b) Scalability**: Spark can without difficulty scale to address increasing records volumes via adding extra nodes to the cluster, allowing horizontal scalability.
**c) Ease of use:** Spark gives a easy and intuitive API that makes it easy to increase information processing programs, making the manner accessible even to non-specialists.
**d) Compatibility**: Spark is well matched with more than one programming languages (Python, Scala, Java, R) and platforms (Hadoop, Kubernetes, cloud).
**e) Active community**: Spark has a massive and active network that gives normal contributions, help, and huge documentation. [22]

f) **Balancing security and usability:** Ensuring sturdy security measures without hindering the usability and accessibility of statistics for healthcare experts.
g) **Cost and resources:** Implementing and preserving advanced safety technology may be resource-extensive and steeply priced.
h) **Evolving threat landscape:** Keeping up with the constantly evolving cyber threats and making sure that safety features are up to date. Ensuring that security measures do no longer disrupt the interoperability of various healthcare systems and facts trade.

## III-3 Use Cases of spark in healthcare

Spark is being used in the healthcare domain for a whole lot of programs, which includes:

a) **Clinical data analysis**: Spark can be used to analyse clinical data, such as electronic health statistics, to perceive trends and enhance quality of care.
b) **Medical research**: Spark may be used for medical research, consisting of genomic records analysis and drug discovery.
c) **Public health**: Spark can be used for public fitness, together with ailment surveillance and outbreak control. [23]

### III-3-1 Example implementation

One example of Spark implementation within the healthcare domain is the PSCAN task. PSCAN is a cloud-based totally research platform that uses Spark to investigate genomic records in cancer studies.

Additional Points:

- Spark can be incorporated with other healthcare records management structures, which include EHRs and information warehouses.
- Spark can be used to develop real-time healthcare applications, consisting of patient monitoring systems and choice help tools.
- Spark is a promising device for advancing personalised remedy and precision healthcare.

## III-4 Designing a parallel and allotted structure for the processing of medical records

a) **Volume and style of information:** Medical facts may be voluminous and sundry, inclusive of scientific pictures, electronic fitness facts, clinical studies facts, and many others.
b) **Data confidentiality and safety:** Medical facts is sensitive and ought to be covered against unauthorized get admission to.

**c) Performance and scalability:** The architecture must be capable of processing information speedy and adapting to increasing statistics volumes.

**d) Availability and reliability:** The structure ought to be to be had at all times and make certain records reliability. [24]

**Components of a parallel and distributed architecture**

A parallel and disbursed architecture for medical facts processing can encompass the following components:

**a) Data get entry to layer:** This layer enables access to numerous assets of clinical facts, including databases, files, and APIs.

**b) Processing layer**: This layer is accountable for processing clinical records, including transformation, evaluation, and visualization.

**c) Storage layer**: This layer stores scientific facts, which include raw statistics, intermediate records, and very last effects.

**d) Management layer**: This layer is liable for managing the structure, which includes tracking, resource making plans, and safety.

## III-5 Tools and technologies selection

### III-5-1 Factors to consider

Volume and variety of data: Medical data can be voluminous and varied, including medical images, electronic health records, clinical research data, etc. Data confidentiality and security: Medical data is sensitive and must be protected against unauthorized access. Performance and scalability: The architecture must be successful in processing data quickly and adapting to the increasing amount of data. Availability and reliability: The structure must be available continuously and ensure data reliability. Budget and resources: The choice of tools and technologies must consider the budget and available resources. [25]

### III-5-2 Tools and technologies

**a) Spark:** A unified data processing framework for both batch and streaming processing. Spark is a popular choice for medical data processing because it is efficient, scalable, and easy to use. Hadoop: An open-source framework for processing large volumes of data. Hadoop can be used to store and process voluminous medical data. Apache Kafka: A distributed data-streaming platform. Apache Kafka can be used to process real-time medical data streams. Kubernetes: A container orchestration system for managing distributed applications. Kubernetes can be used to manage deployed medical data processing packages on machine clusters.

**b) Examples of applications:** Clinical data analysis: Spark can be used to analyze clinical data, such as electronic health records, to detect trends and improve the quality of care. Medical research: Spark can be employed in medical research, including genomic

data analysis and drug discovery. Public health: Spark can be utilized in public health, including disease surveillance and epidemic management.

## III-6 Integration of spark with other tools

**a) Enhanced data processing:** Integrating Spark with other equipment lets in for greater efficient and powerful facts processing, allowing healthcare providers to advantage well timed insights from big datasets.

**b) Interoperability:** Ensures that distinct structures can paintings collectively harmoniously, making an allowance for the seamless exchange and utilization of facts.

**c) Scalability:** Facilitates the managing of developing information volumes by leveraging the strengths of different gear and technologies.

Improved Decision-Making: Provides healthcare experts with comprehensive data analytics competencies, leading to better patient care and operational efficiencies.

## III-7 Key integration tools

**a) Hadoop distributed file system (HDFS):**

Spark can examine from and write to HDFS, enabling efficient garage and processing of huge datasets. HDFS presents a scalable and fault-tolerant storage solution, complementing Spark's processing energy.

**b) Apache mesos:** Mesos acts as a cluster manager, permitting Spark to run along different massive records frameworks. It gives aid isolation and sharing across dispensed packages, improving Spark's overall performance and flexibility.

**c) Apache cassandra:** Integrating Spark with Cassandra allows real-time analytics on dispensed, NoSQL databases. Cassandra's scalability and Spark's processing skills make it viable to carry out complicated analytics on vast amounts of statistics.

**d) Apache kafka:** Kafka is used for constructing real-time records pipelines and streaming applications. By integrating Spark with Kafka, healthcare groups can technique and examine streaming records in actual-time, enabling timely interventions and insights.

**e) Apache hive:** Hive permits for the querying and evaluation of large datasets saved in HDFS. Running Hive queries via Spark improves query performance and scalability, leveraging Spark's in-memory processing abilities.

**f) Apache flume:** Flume is used for consuming big amounts of log records. Integrating Spark with Flume allows for the actual-time evaluation of log data, assisting to identify and address operational problems directly.

**g) Machine learning libraries (MLlib):** Spark’s MLlib provides scalable gadget mastering algorithms. Integrating MLlib with other information resources and gear permits superior predictive analytics and personalised medication.

**h) GraphX**: GraphX is Spark's API for graph processing. Integrating GraphX with different records systems allows for complicated community evaluation, which includes analyzing sickness spread patterns or affected person referral networks.

**i) Spark SQL:** Spark SQL permits the processing of based records.

Integrating Spark SQL with various databases and information warehouses lets in for efficient querying and statistics manipulation.

## III-8 Real-world applications of EHRs

Integrating Spark with EHR structures allows for real-time processing and evaluation of patient records, improving scientific choice-making and affected person effects.

**a) Data warehousing:** Combining Spark with records warehousing solutions enables the aggregation and evaluation of big volumes of healthcare statistics, assisting strategic planning and operational efficiency.

**b) Patient monitoring systems:** Real-time integration with patient tracking gadgets and structures enables non-stop data analysis, bearing in mind early detection of crucial fitness occasions and timely interventions.

**c) Clinical decision support systems (CDSS):** Integrating Spark with CDSS complements the ability to manner and examine clinical statistics, supplying healthcare specialists with precious insights and pointers.

## III-9 Challenges and solutions

**a) Data compatibility:** Ensuring that different statistics codecs and systems are like-minded may be difficult. The solution is to use data integration gear and ETL (Extract, Transform, and Load) approaches to standardize records codecs.

**b) System performance:** Integrating multiple tools can effect system performance and speed. The solution is to optimize aid allocation and use green data processing strategies to preserve performance stages.

**c) Security and compliance:** Maintaining statistics safety and compliance across included systems is critical. The solution is to implement sturdy safety features and make sure compliance with applicable regulations and standards.

## III-10 Data security and encryption technologies

### III-10-1 Importance of data security in healthcare

**a) Patient confidentiality**: Ensuring that affected person information stays confidential is a cornerstone of scientific ethics. Unauthorized get entry to to sensitive facts can lead to breaches of privacy and trust.

**b) Compliance with regulations**: Healthcare providers need to follow various policies along with GDPR, HIPAA, and HITECH, which mandate stringent information protection measures.

**c) Risk management**: Effective records safety mitigates the dangers associated with facts breaches, consisting of economic losses, prison consequences, and reputational harm.

**d) Integrity and availability**: Ensuring data integrity and availability is vital for correct prognosis and effective remedy. Data tampering or loss can critically affect patient care.

## III-10-2 Key security threats to medical data

**a) Cyber attacks**: Healthcare information is a high goal for cyber assaults, inclusive of ransom-ware, phishing, and malware.

**b) Insider threats**: Employees or insiders with get entry to to touchy records can pose big dangers if they misuse or improperly take care of facts.

**c) Data breaches**: Unauthorized access to databases and structures can cause big-scale information breaches, compromising patient information.

**d) Human error**: Mistakes including unintentional records deletion or misconfiguration of protection settings also can jeopardize statistics safety.

## III-10-3 Data encryption technologies

**a) Symmetric encryption**: Uses a single key for both encryption and decryption. It is fast and efficient for massive statistics sets but requires stable key management.
Examples: Advanced Encryption Standard (AES), Data Encryption Standard (DES)

**b) Asymmetric encryption**: Uses a couple of keys (public and personal) for encryption and decryption. It complements protection however is computationally intensive.
Examples: RSA, Elliptic Curve Cryptography (ECC)

**c) Hash functions:** Generate a fixed-size hash fee from input statistics, making sure information integrity by detecting any changes to the statistics.
Examples: SHA-256, MD5

**d) Hybrid encryption:** Combines symmetric and asymmetric encryption to leverage the blessings of both. Typically, symmetric encryption is used for information transmission, and asymmetric encryption is used for stable key change.

**e) Data at Rest:** Encrypting stored records to guard it from unauthorized get entry to, especially on devices and databases.

**f) Data in transit:** Ensuring that information transmitted over networks is encrypted to prevent interception and eavesdropping.

**g) End-to-end encryption:** Encrypting information from the source to the destination to make certain it remains stable at some point of its lifecycle.

**h) Encryption key management:** Implementing stable strategies for key generation, distribution, garage, and rotation to defend encryption keys.

## III-11 Advanced security measures

**a) Multi-factor authentication (MFA):** Enhancing safety by using requiring multiple styles of verification earlier than granting access to sensitive records.

**b) Role-based access control (RBAC):** Limiting get admission to to information primarily based on the users function inside the agency, ensuring that individuals best get admission to information important for their obligations.

**c) Audit logs and monitoring:** Keeping precise logs of facts access and usage, and constantly monitoring systems to come across and reply to safety incidents.

**d) Data masking and tokenization:** Techniques to obfuscate touchy data, making it unreadable to unauthorized customers while maintaining its usability for legal purposes.

## III-12 Data governance and compliance tools

**a) Data quality and integrity:** Ensuring that facts is correct, complete, and reliable is critical for making knowledgeable clinical selections and providing first rate affected person care.

**b) Regulatory compliance:** Adhering to legal guidelines and regulations consisting of GDPR, HIPAA, and HITECH, which mandate specific necessities for information safety and patient privacy.

**c) Risk management:** Identifying and mitigating dangers related to statistics breaches, unauthorized get entry to, and facts misuse.

**d) Operational efficiency:** Streamlining information control strategies and enhancing the efficiency of statistics handling and reporting.

**e) Data stewardship:** Assigning duty for data management and ensuring that facts stewards are responsible for maintaining statistics quality and compliance.

**f) Data policies and standards**: Developing and imposing policies and standards for statistics collection, storage, processing, and sharing.

**g) Data classification**: Categorizing data based totally on its sensitivity and criticality to apply appropriate protection measures.

**h) Data lifecycle management**: Managing data all through its lifecycle from advent and use to archiving and deletion

## III-13 Compliance tools and technologies

**a) Data loss prevention (DLP):** Tools that monitor and guard facts from unauthorized get right of entry to, leaks, and breaches.

**b) Identity and access management (IAM):** Solutions that manage user get entry to to information primarily based on their roles and responsibilities, ensuring that only legal employees can get admission to touchy information.

**c) Encryption tools:** Technologies that encrypt records at rest and in transit to guard it from unauthorized get entry to and make certain information privacy.

**d) Audit and monitoring tools:** Systems that song and log records access and usage, supplying an audit trail for compliance reporting and incident response.

## III-14 Implementation of data governance frameworks

**a) Establishing a governance structure:** Forming a statistics governance committee that consists of stakeholders from distinct departments to oversee records governance projects.

**b) Developing data policies:** Creating complete data regulations that define procedures for information control, safety, and compliance.

**c) Training and awareness:** Educating personnel approximately facts governance regulations, their roles in maintaining information first-class, and the importance of compliance.

**d) Regular audits and assessments:** Conducting periodic audits to evaluate records governance practices and ensure adherence to regulatory necessities.

## III-15 Benefits of effective data governance

**a) Improved data quality:** Enhanced accuracy, consistency, and reliability of information used for scientific selection-making.

**b) Regulatory readiness:** Being nicely-organized for regulatory audits and inspections, reducing the hazard of non-compliance consequences.

**c) Enhanced security:** Stronger protection against statistics breaches and unauthorized get entry to, safeguarding affected person information.

**d) Operational efficiency:** Streamlined statistics management methods that reduce redundancies and improve normal efficiency.

## III-16 Challenges and solutions

**a) Complex regulatory environment:** Navigating the complex and evolving landscape of healthcare regulations.

**b) Solution:** Employing specialised compliance equipment and searching for felony information to live updated on regulatory modifications.

**c) Data silos:** Managing information this is dispersed across distinct systems and departments.

**d) Solution:** Implementing included data management platforms that offer a unified view of statistics.

**e) Resource constraints:** Limited sources for enforcing comprehensive statistics governance applications.

**f) Solution**: Prioritizing critical areas for governance and steadily increasing the scope as resources permit.

**g) User resistance:** Resistance from group of workers to undertake new facts governance practices.

The solution is providing training and demonstrating the benefits of data governance to advantage buy-in from all stakeholders.

## Conclusion

Apache Spark's capabilities and advantages make it a precious asset for processing large volumes of medical records. The use instances and instance implementation tested its practical programs and the good sized improvements it could convey to records analysis in healthcare. As Spark continues to evolve, its integration with other technology and better security measures will in addition solidify its position in advancing medical statistics processing.

# Chapter IV Development and deployment of the system

## Introduction

The sensible software of theoretical principles in disbursed systems and Apache Spark culminates inside the improvement and deployment of a strong gadget for medical information processing. This bankruptcy outlines the vital stipulations, gear, and technologies for machine installation and deployment. Detailed commands on putting in the environment and imposing the machine may be supplied, making sure a complete understanding of the deployment technique.

## IV-1 Why do we need to install prerequisites

During our research to develop and deploy a system based on Apache Spark and TensorFlow, we encountered several challenges related to the installation requirements of these tools. We followed multiple steps to ensure the appropriate environment was available, which required significant effort to resolve the issues we faced and Throughout this research, we faced multiple technical challenges, but by correctly installing each prerequisite, we were able to overcome these obstacles and ensure the system operated efficiently. This effort reflects our dedication to solving technical problems and providing a stable and effective runtime environment

a) **Installing Java**: Spark relies on Java to run its applications, and we encountered an issue with running Spark because Java was not initially installed. We installed Java according to the correct instructions to solve this problem and ensure Spark ran successfully.

b) **Installing OpenSSH**: To ensure secure communication between nodes in the Spark system, we had to install OpenSSH. Without OpenSSH, the nodes could not communicate with each other without a password, which hindered the system's proper operation. We set up OpenSSH to secure the communication between nodes.

c) **Installing Python 3 and pip3**: Since many applications used with Spark depend on Python, we faced a challenge in installing and running these applications. We installed Python 3 and pip3 to solve this issue and facilitate the management of the required libraries.

d) **Installing Scala**: To use Spark's API with Scala, it was necessary to install Scala. Without Scala, we could not develop or run applications using Spark's Scala API. Therefore, we installed Scala to overcome this obstacle.

e) **Installing sbt (Scala Build Tool)**: Managing dependencies and building software projects effectively was not possible without sbt. We installed it to facilitate the integration and configuration of Spark projects written in Scala.

f) **Installing PySpark**: We could not use Python with Spark without PySpark, so we installed it to enable developers to use Spark for large-scale data processing with Python.

g) **Installing NumPy**: To handle advanced mathematical operations in applications, we needed to install the NumPy library. It was essential to solve scientific computation issues in Python.

h) **Installing scikit-learn**: To ensure the ability to use machine-learning tools in Python, we installed the scikit-learn library, which was necessary for analytical and modeling tasks.

i) **Installing CUDA and TensorFlow**: To run TensorFlow on an NVIDIA GPU, it was necessary to install CUDA and cuDNN. Without these tools, TensorFlow could not leverage the GPU's capabilities, significantly affecting performance in deep learning tasks.

## IV-2 Installation of prerequisites

Before deploying Apache Spark in a standalone cluster, it is far crucial to make certain that each one essential prerequisites are established and configured efficiently. This consists of Java, OpenSSH, and different vital equipment required for a easy installation and operation of Spark. [26]

### IV-2-1 Installation of Java

Java is a number one dependency for jogging Spark, as Spark applications are written in Java. Here is a detailed guide on how we established Java on our systems: [27]

**a) Installing Java:** we use the JDK installer, we proceeded with the installation. For Linux structures, the process worried extracting the tar.Gz file and shifting the JDK folder to an appropriate listing, generally /usr/lib/jvm. We ensured that we accompanied the detailed set up instructions furnished with the aid of Oracle, which covered accepting the license agreement and deciding on the set up direction.

```
# sudo apt update
# sudo apt install default-jdk
# sudo apt install default-jre
```

**b) Configuring Environment Variables:** Post-set up, putting in the surroundings variables is vital for the device to understand the Java installation. We configured the JAVA_HOME environment variable to point to the JDK set up listing. On Windows, this

concerned going to System Properties -> Environment Variables and including a brand new machine variable named JAVA_HOME with the JDK route as its price. Similarly, on Linux, we introduced the subsequent strains to the .Bashrc or .Bash_profile document. These steps ensure that the java and javac instructions are available from the command line, and the device can locate the Java binaries.

**c) Verification:** To verify that Java changed into established effectively, we ran the subsequent instructions within the terminal:

```
# java -version
# javac -version
```

These commands back the installed model of Java, verifying that the installation and configuration have been successful.

By meticulously following those steps, we ensured that Java turned into efficiently mounted and configured on all systems, providing a solid foundation for deploying and jogging Spark successfully

### IV-2-2 Installation of OpenSSH

OpenSSH is used for secure conversation between nodes in a Spark cluster. Here are the steps we accompanied to put in and configure OpenSSH: [28]

**a) Installing OpenSSH:** On Linux-based totally systems, OpenSSH may be hooked up the use of the package supervisor specific to the distribution.

For Ubuntu, the setup is performed the usage of the apt package deal supervisor:

```
# sudo apt-get update
# sudo apt-get install openssh-
```

These commands down load and deploy the OpenSSH server package deal, allowing the machine to act as an SSH server.

**b) Starting and Enabling OpenSSH:** After installation, we want to start the SSH provider and make sure it starts offevolved routinely on boot.

On Ubuntu:

```
# sudo systemctl start ssh
# sudo systemctl enable ssh
```

These commands ensure that the SSH provider is walking and could automatically begin on gadget boot.

**c) Setting Permissions:** We ensured that the SSH listing and key documents have the precise permissions:

```
#  chmod 700 ~/.ssh
# chmod 600 ~/.ssh/authorized_keys
```

These permissions make certain that the SSH keys are steady and best reachable by using the owner.

**d) Testing SSH Connectivity:** To verify that the configuration turned into a success, we attempted to SSH from the grasp node to each employee node without a password:

```
# ssh 192.168.X.X
```

If configured efficiently, this command logs into the employee node without prompting for a password.

By following these steps, we efficiently hooked up and configured OpenSSH, ensuring steady and seamless communique between the nodes in our Spark cluster.

### IV-2-3 Installation of Python 3 and pip3

Python three is required to use Spark, as many Spark packages make use of Python. Below are the steps to install Python 3 and pip3: [29]

Checking for Existing Python three Installation

**a) Verify if Python 3 is already mounted:** Open the terminal and execute the following command to check the version of Python 3**:**

```
# python3 –version
```

If Python three is installed, this command will return the established version of Python.

**b) Installing Python 3:** If Python 3 is uninstalled, use the bundle supervisor to put in it. Here are the steps for Ubuntu:

```
# sudo apt-get update
# sudo apt-get install python3
```

These commands update the bundle statistics and deploy Python 3.

**c) Validate the Installation:** After the installation, verify the version of Python three by using jogging the subsequent command:

```
# python3 –version
```

This command have to return the model of Python three, confirming that the installation was a success.

**d) Installing pip3:** pip3 is the package management device for Python three, permitting the set up of Python libraries and dependencies. Install pip3 the use of the subsequent command:

```
# sudo apt-get install python3-pip
```

This command installs pip3 on the machine.

**e) Validate the Installation of pip3:** Finally, verify that pip3 is running correctly through checking its version:

```
# pip3 –version
```

This command have to go back the version of pip3, indicating that pip3 has been established successfully.

### IV-2-4 Installation of Scala

Scala is a programming language required for developing and going for walks Spark packages, specifically for folks who want to apply Spark's Scala API. Below are the steps to put in Scala on your device: [30]

**a) Verify if Scala is already set up:** Open the terminal and execute the subsequent command to test the version of Scala:

```
# scala-version
```

If Scala is mounted, this command will return the hooked up version of Scala.

**b) Installing Scala:** If Scala is not set up, download the state-of-the-art version of Scala from the legitimate website scala-lang.Org. Download the binary file corresponding to your running machine. Extract the downloaded archive. For instance, for a tar.Gz archive on Linux, use the subsequent command:

```
# sudo tar xvf scala-2.12.10.tgz
```

Move the extracted folder to a directory of your preference, which includes /usr/local/scala:

```
# sudo mv scala-2.12.10 /usr/local/scala
```

**c) Configure environment variables:** Add Scala on your PATH with the aid of configuring environment variables. Add the subsequent traces for your ~/.Bashrc:

```
# nano ~/.bashrc
```

```
export PATH=$PATH:/usr/local/scala/bin
```

Reload the shell configuration report to use the changes:

```
# source ~/.bashrc
```

**d) Validate the installation:**

After configuring the surroundings variables, validate the installation via checking the version of Scala:

```
# scala-version
```

By following these steps, you ensure that Scala is efficiently installed and configured, imparting a robust environment for developing and jogging Spark applications the use of Scala.

### IV-2-5 Installation of sbt

sbt (Scala Build Tool) is the construct device for Scala, essential for managing dependencies and constructing Scala projects. [31]

**a) Why install sbt?** Sbt (Scala Build Tool) is the construct tool for Scala. Although its set up isn't always in reality vital for jogging easy Spark applications, it's far distinctly advocated for numerous motives:

**b) Dependency management:** sbt helps the management of dependencies on your Scala venture. You can without problems add external libraries on your assignment by using affirming them in a build.Sbt document.

**c) Compilation and build:** sbt automates the method of compiling and constructing your Scala projects. It handles the vital steps to convert your source code into an executable report.

**d) Development environment:** sbt presents an interactive improvement environment, with instructions to check, package deal, and run your code.

**e) Compatibility with Spark:** Many Spark initiatives written in Scala use sbt for dependency control and the construct technique. This simplifies the integration and configuration of your Spark assignment.

**f) Install sbt:** To deploy sbt, add the sbt repository in your package management gadget. On Ubuntu, upload the following strains to /and many others/apt/assets.List.D/sbt.Listing:

```
# echo "deb https://dl.bintray.com/sbt/debian /" | sudo tee-a
/etc/apt/sources.list.d/sbt.list
# sudo apt-key adv--keyserver hkp://keyserver.ubuntu.com:80--
recv 642AC823
# sudo apt-get update
# sudo apt-get install sbt
```

### IV-2-6 Installation of PySpark

PySpark is the Python API for Apache Spark, allowing Python developers to harness the electricity of Spark for large-scale information processing. The following phase outlines the stairs required to install PySpark in a Python surroundings. [32]

**a) Installing PySpark:** Once the conditions are met, you may proceed with the installation of PySpark. The advocated approach for installing PySpark is thru pip, as it ensures that all dependencies are efficaciously treated.

To installation PySpark, execute the following command:

```
# pip3 install
```

This command downloads and installs the contemporary model of PySpark and its dependencies.

**b) Verification of installation:** After the installation, you can confirm that PySpark is installed successfully by means of beginning the PySpark shell. Open a terminal and kind:

```
# pyspark
```

If PySpark is mounted correctly, this command will release the PySpark shell, showing the Spark model and the Python model getting used.

**c) Setting up the environment:** To make certain that PySpark can run efficaciously, it's far crucial to configure the surroundings nicely. This consists of putting the SPARK_HOME surroundings variable to factor to the Spark installation directory.

d) **Setting environment variables:** Add the subsequent lines on your ~/.Bashrc:

```
export SPARK_HOME=/opt/spark

export PATH=$PATH:$SPARK_HOME/bin
```

Reload the configuration report to apply the adjustments:

```
# source ~/.bashrc
```

### IV-2-7 Installation of NumPy

NumPy is a essential package for clinical computing in Python, offering help for arrays, matrices, and a massive collection of mathematical capabilities to perform on those statistics systems. The following segment outlines the stairs required to put in NumPy in a Python environment. [33]

**a) Installing NumPy:** Once the prerequisites are met, you can continue with the set up of NumPy. The encouraged approach for putting in NumPy is thru pip, because it guarantees that every one dependencies are successfully dealt with.

To deploy NumPy, execute the subsequent command:

```
# pip install numpy
```

This command downloads and installs the latest version of NumPy and its dependencies.

**b) Verification of installation:** After the set up, you could confirm that NumPy is set up efficiently via establishing a Python shell and importing NumPy:

```
# python3
```

Then, in the Python shell, type:

```
import numpy
print(numpy.__version__)
```

If NumPy is installed effectively, this command will print the version of NumPy this is hooked up.

**c) Setting up the environment:** To make sure that NumPy can run correctly, specially for huge-scale numerical computations, it's far vital to set up the environment nicely.

**d) Optimizing performance:** NumPy can be optimized with various libraries like BLAS (Basic Linear Algebra Subprograms) and LAPACK (Linear Algebra Package) for improved performance. These libraries are regularly included with the NumPy package, but ensuring they're well configured can yield overall performance advantages.

On Ubuntu, you may deploy optimized libraries with:

```
#  sudo apt-get install libblas-dev liblapack-dev
```

These libraries provide optimized routines for numerical operations, which NumPy can leverage.

**e) Testing NumPy:** To make certain that NumPy is effectively established and configured, you may create a simple check script in Python:

- Creating a Test Script: Write a script named test_numpy.Py with the subsequent content material:

```
#  nano test_numpy.py
```

```
import numpy as np
a = np.array([1, 2, 3])
print("Array:", a)
print("Mean:", np.mean(a))
print("Standard Deviation:",
np.std(a))
```

Run the script the use of:

```
#  python test_numpy.py
```

If NumPy is installed and configured efficaciously, the script will print the array and the calculated mean and standard deviation, confirming that NumPy is operational.

### IV-2-8 Installation of scikit-learn

Scikit-learn is a powerful and person-friendly Python library for gadget mastering, offering simple and efficient tools for records analysis and modelling. The following section outlines the stairs required to install scikit-learn in a Python environment. [34]

**a) Installing scikit-learn:** Once the prerequisites are met, you could continue with the installation of scikit-learn . The recommended method for putting in scikit-learn is via pip, as it ensures that each one dependencies are correctly treated. To deploy scikit-learn, execute the subsequent command:

```
# pip install scikit-learn
```

This command downloads and installs the ultra-modern model of scikit-examine and its dependencies.

**b) Verification of installation:** After the installation, you can verify that scikit-learn is hooked up correctly by means of commencing a Python shell and importing the library:

```
# python 3
```

Then, in the Python shell, kind:

```
import sklearn;
print(sklearn.__version_
```

If Scikit-learn is established effectively, this command will print the model of scikit-learn this is hooked up.

**c) Setting up the environment:** To make certain that scikit-learn can run correctly, especially for huge-scale gadget learning duties, it's miles essential to set up the environment properly.

### IV-2-9 Installing CUDA on Ubuntu 22.04 for Running TensorFlow

To correctly run TensorFlow on an NVIDIA GPU, CUDA and cuDNN have to be mounted. Below are the unique steps for installing CUDA 12.5 on Ubuntu 22.04 from the legit NVIDIA website. [35]

**a) Set up preferences:** The first step is to download the choice file for the CUDA repository and pass it to the proper area at the machine.

```
# wget
https://developer.download.nvidia.com/compute/cuda/repos/ ubuntu2204/x86_64/cuda-ubuntu2204.pin

# sudo mv cuda-ubuntu2204.pin
/etc/apt/preferences.d/cuda-repository-pin-600
```

**b) Add the local CUDA repository:** Next, download and install the nearby CUDA repository bundle.

```
# wget
https://developer.download.nvidia.com/compute/cuda/12.5.0/local_installers/cuda-repo-ubuntu2204-12-5-local_12.5.0-555.42.02-1_amd64.deb

# sudo dpkg-i cuda-repo-ubuntu2204-12-5-local_12.5.0-555.42.02-1_amd64.deb
```

**c) Add the GPG key:** After installing the bundle, copy the GPG key for the CUDA repository.

```
# sudo cp /var/cuda-repo-ubuntu2204-12-5-local/cuda-*-keyring.gpg /usr/share/keyrings/
```

Now, replace the package lists to get the present day statistics from the CUDA repository.

```
# sudo apt-get update
```

**d) Install CUDA Toolkit:** Install the CUDA Toolkit, which incorporates important tools for growing applications with CUDA.

```
# sudo apt-get-y install cuda-toolkit-12-
```

**e) Install NVIDIA Drivers:** To ensure the GPU capabilities effectively, deploy the proper NVIDIA drivers.

```
# sudo apt-get install-y cuda-drivers

# sudo apt-get install-y nvidia-driver-555-open

# sudo apt-get install-y cuda-drivers-555
```

Role of Steps in Installing TensorFlow

- Setting Up Preferences: Ensures that CUDA packages are prioritized in the course of installation and updates.
- Adding the Local CUDA Repository: Facilitates get entry to to essential packages for putting in CUDA.
- Adding the GPG Key: Secures the verification of applications downloaded from the CUDA repository.
- Updating Package Lists: Ensures the machine makes use of the contemporary versions of packages.
- Installing CUDA Toolkit: Provides a comprehensive development environment for CUDA programs.
- Installing NVIDIA Drivers: Ensures that the GPU operates effectively with CUDA.
- After completing these steps, the gadget is ready for TensorFlow installation and usage with an NVIDIA GPU to enhance performance in training and inference

### IV-2-10 Installation of TensorFlow

TensorFlow is an open-supply device gaining knowledge of framework evolved by Google for constructing and training system gaining knowledge of models. The following phase outlines the stairs required to put in TensorFlow in a Python surroundings. [36]

**a) Installing TensorFlow:** Once the prerequisites are met, you may continue with the installation of TensorFlow. The encouraged approach for installing TensorFlow is via pip, because it ensures that each one dependencies are efficaciously treated. To set up TensorFlow, execute the subsequent command:

```
# pip install tensorflow
```

This command downloads and installs the latest model of TensorFlow and its dependencies.

**b) Verification of Installation:** After the set up, you could verify that TensorFlow is set up efficiently by using starting a Python shell and importing the library:

```
# Python3
```

Then, within the Python shell, type:

```
# import tensorflow as tf;
print(tf.__version__)
```

If TensorFlow is hooked up successfully, this command will print the model of TensorFlow this is established.

## IV-3 Installation and deployment of Spark in standalone mode

Now that the prerequisites are mounted, we are able to set up Spark in standalone mode on our cluster. In this mode, Spark manages its personal resources without requiring an external supervisor. Here are the steps to put in Spark and deploy the cluster: [37]

**a) Downloading Spark:** Download the modern day model of Spark from its professional internet site apache.Org.

**b) Extracting the archive:** Once the down load is whole, extract the archive on every node of the cluster in which Spark can be mounted.

**c) Configuration of files:** Configure the spark-env.Sh and spark-defaults.Conf files in step with the needs and specifics of your surroundings. These files comprise configurations including surroundings variables, reminiscence and CPU settings, etc.

**d) Deployment of the Spark cluster:** Now that Spark is mounted on each node, we will installation the cluster:

```
// Start the Spark master and all slaves is listed into the master configuration just using the master

# SPARK_HOME/sbin/start-master.sh

# SPARK_HOME/sbin/start-slaves.sh

// if we need tu conect onec noed worker using the same worker machine

# SPARK_HOME/sbin/start-slave.sh spark://192.168.@.MASTER:7077
```


*Figure 2 :The Spark web UI displays worker resource utilization during the execution of the script.*

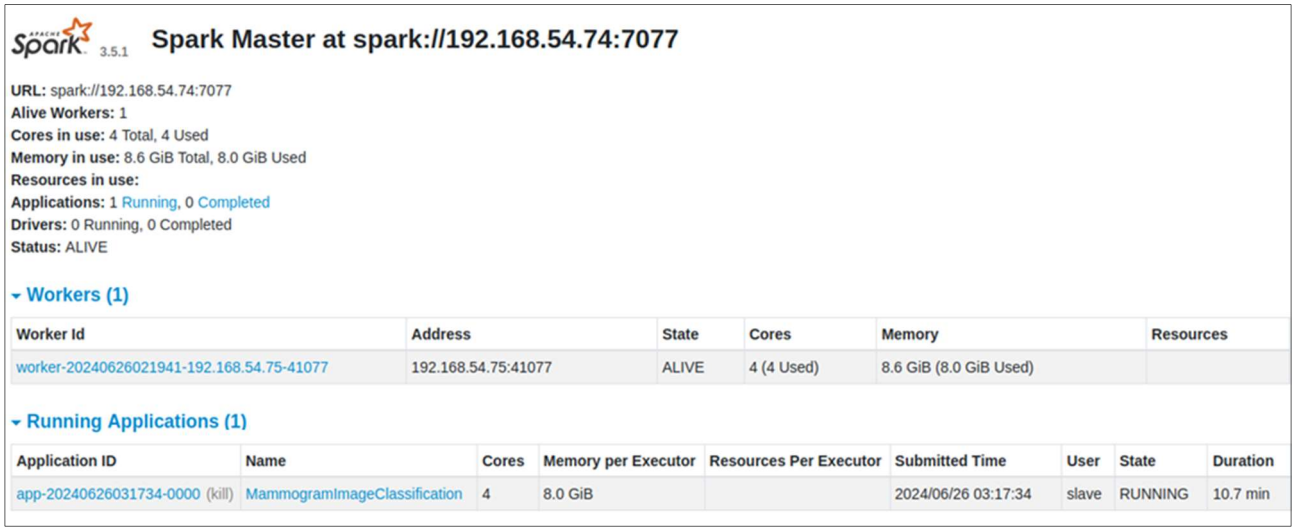
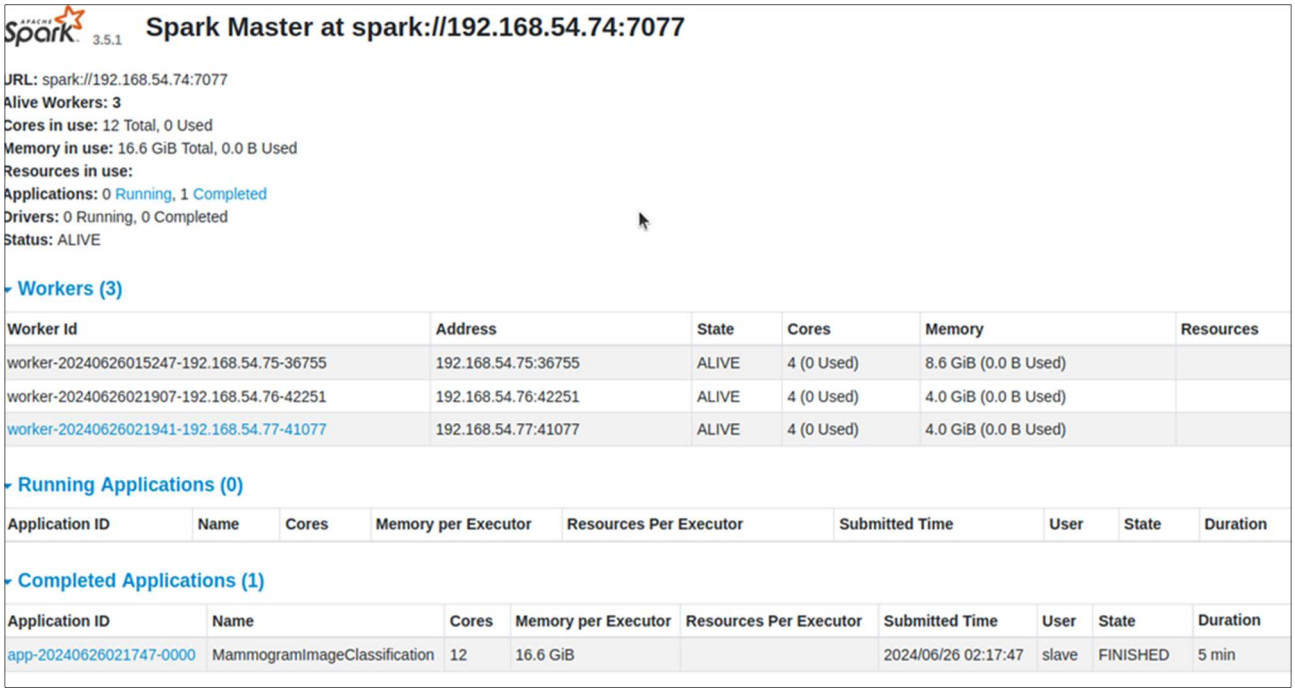



*Figure 3 : The Spark web UI of the master node displays worker resource utilization during the execution of the script*



Spark 3.5.1 **Spark Master at spark://192.168.54.74:7077**

**URL:** spark://192.168.54.74:7077
**Alive Workers:** 3
**Cores in use:** 12 Total, 0 Used
**Memory in use:** 16.6 GiB Total, 0.0 B Used
**Resources in use:**
**Applications:** 0 Running, 1 Completed
**Drivers:** 0 Running, 0 Completed
**Status:** ALIVE

**Workers (3)**

| Worker Id | Address | State | Cores | Memory | Resources |
|---|---|---|---|---|---|
| worker-20240626015247-192.168.54.75-36755 | 192.168.54.75:36755 | ALIVE | 4 (0 Used) | 8.6 GiB (0.0 B Used) | |
| worker-20240626021907-192.168.54.76-42251 | 192.168.54.76:42251 | ALIVE | 4 (0 Used) | 4.0 GiB (0.0 B Used) | |
| worker-20240626021941-192.168.54.77-41077 | 192.168.54.77:41077 | ALIVE | 4 (0 Used) | 4.0 GiB (0.0 B Used) | |

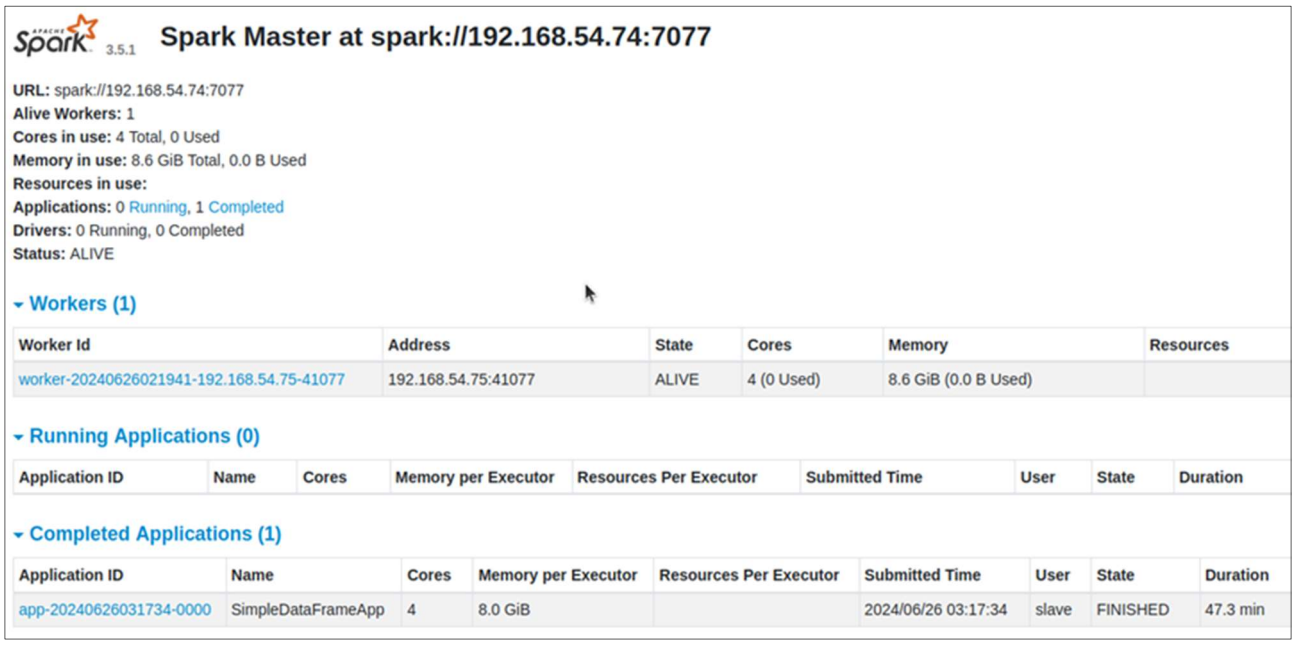
**Running Applications (0)**

| Application ID | Name | Cores | Memory per Executor | Resources Per Executor | Submitted Time | User | State | Duration |
|---|---|---|---|---|---|---|---|---|

**Completed Applications (1)**

| Application ID | Name | Cores | Memory per Executor | Resources Per Executor | Submitted Time | User | State | Duration |
|---|---|---|---|---|---|---|---|---|
| app-20240626021747-0000 | MammogramImageClassification | 12 | 16.6 GiB | | 2024/06/26 02:17:47 | slave | FINISHED | 5 min |

*Figure 4: After the execution completes with 3 workers, the Spark web UI of the master shows that we achieved better execution time.*



Spark 3.5.1 **Spark Master at spark://192.168.54.74:7077**

**URL:** spark://192.168.54.74:7077
**Alive Workers:** 1
**Cores in use:** 4 Total, 0 Used
**Memory in use:** 8.6 GiB Total, 0.0 B Used
**Resources in use:**
**Applications:** 0 Running, 1 Completed
**Drivers:** 0 Running, 0 Completed
**Status:** ALIVE

**Workers (1)**

| Worker Id | Address | State | Cores | Memory | Resources |
|---|---|---|---|---|---|
| worker-20240626021941-192.168.54.75-41077 | 192.168.54.75:41077 | ALIVE | 4 (0 Used) | 8.6 GiB (0.0 B Used) | |

**Running Applications (0)**

| Application ID | Name | Cores | Memory per Executor | Resources Per Executor | Submitted Time | User | State | Duration |
|---|---|---|---|---|---|---|---|---|

**Completed Applications (1)**

| Application ID | Name | Cores | Memory per Executor | Resources Per Executor | Submitted Time | User | State | Duration |
|---|---|---|---|---|---|---|---|---|
| app-20240626031734-0000 | SimpleDataFrameApp | 4 | 8.0 GiB | | 2024/06/26 03:17:34 | slave | FINISHED | 47.3 min |

*Figure 5: After the execution completes with one worker, the Spark web UI of the master shows that we have a long execution time.*

e) **Starting the master node and slave nodes:** Use the supplied Spark scripts to start the master node and slave nodes. These scripts may be located within the sbin listing of your Spark set up. Ensure that the slave nodes are properly configured to connect to the master node.

f) **Checking the web interface:** Access the Spark Web interface to confirm that the cluster is operational. By default, the Web interface is offered at http://localhost:8080 from the master node.

### IV-4 Submitting Spark applications:

Use the spark-submit command to publish your Spark programs to the cluster. Make certain to specify all necessary parameters, which includes the course on your software, Spark configuration, and many others.

```
// this how we run python into the spark cluster

# spark-submit --master  spark://master.url:7077   path/to/script.py
```

### IV-5 The application

We used mammogram photos to classify benign and malignant breast most cancers. The dataset comprised photographs categorized as either benign or malignant, which have been used to teach and validate the version. This classification is vital for early detection and treatment of breast most cancers.

### IV-5-1 Parallel distributed data processing

We create and run an application for parallel-distributed facts processing the use of a Convolutional Neural Network (CNN) model to categorise mammogram pics as malignant or benign, we are able to observe these steps: [38]

VGG16 is a convolutional neural network architecture that turned into developed through the Visual Graphics Group at Oxford and is known for its simplicity and effectiveness. It has sixteen layers and has been broadly used for image category responsibilities, making it a sturdy preference for our mammogram classification problem.

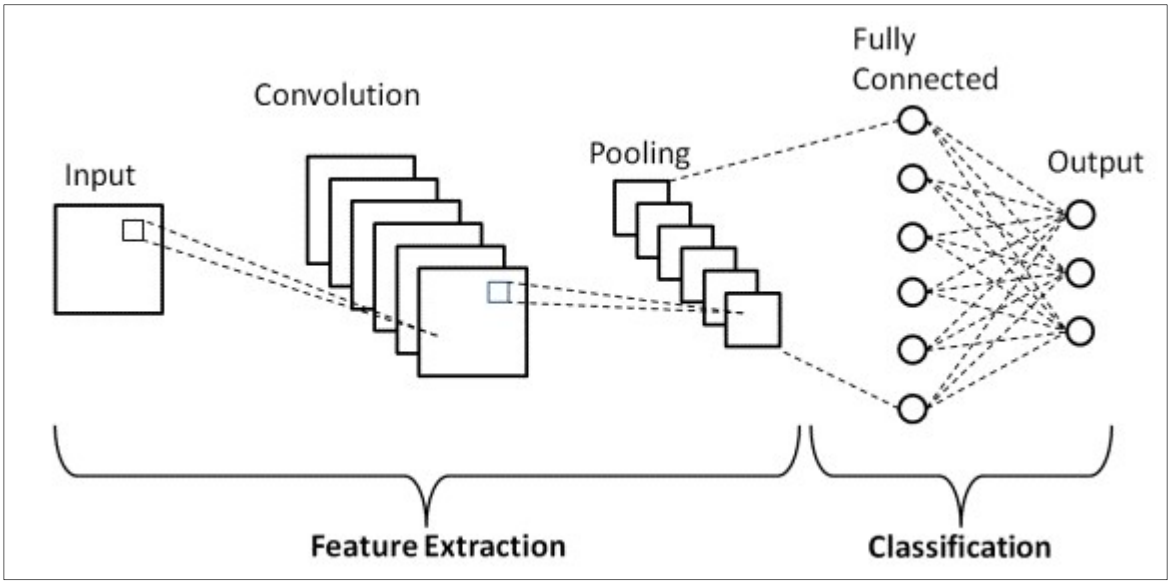



*Figure 6:basic cnn architecture*

### IV-5-2 Tools and techniques used

Multiple libraries were used such as TensorFlow, Keras, NumPy, PIL (Python Imaging Library), PySpark, Elephas, and Scikit-examine.

### IV-5-3 Deep learning model

The VGG16 model pre-trained on the ImageNet dataset was used.

**a) Spark:** Apache Spark turned into used to distribute the loading, processing, and training duties throughout computing nodes.

**b) Data Splitting:** The train_test_split function from Scikit-research turned into used to divide the information into training and validation sets.

### IV-5-4 Implementation Steps

**a) Setting up Spark session:** Initialized a Spark session to facilitate allotted records processing. This step is critical because it sets up the surroundings for dispensed computation, allowing us to handle huge datasets and complex computations efficaciously.

**b) Image processing:**

- **Image resizing:** Images had been resized to 224x224 pixels. This step ensures that each one photos are of a steady length, that is necessary for feeding into the neural community.
- **Image converting:** Images were converted to RGB layout in the event that they have been now not already. This standardizes the photograph information, making sure compatibility with the VGG16 model which expects RGB enter.
- **Normalisation:** The preprocess_input characteristic from Keras became used for normalization. Normalization facilitates in speeding up the convergence of the neural network throughout schooling

**c) Creating DataFrame:** Created a DataFrame from image paths the usage of PySpark. This structure allows for green dispensed processing of photos, leveraging Spark's abilties to handle huge-scale facts.

**d) Loading and distributing images:** Distributed photograph loading and processing duties throughout computing nodes using PySpark. This step is important to utilize the overall electricity of dispensed computing, enabling parallel processing and lowering the overall time required for data instruction.

**e) Images and labels extraction:** Images and labels had been extracted and converted to NumPy arrays. This conversion is essential for compatibility with the Keras deep studying library, which requires enter statistics in NumPy array format.

**f) Splitting data:** The facts turned into break up into education and validation units. This is a popular exercise in device studying to evaluate the performance of the model on unseen information and prevent overfitting.

**g) Setting up VGG16 model:**

- Freezing Base Layers**:** The base layers were frozen to save you retraining. This step leverages the pre-skilled weights on ImageNet, saving computational sources and improving version overall performance.
- Adding Custom Layers: Dense and dropout layers had been added on top of the bottom model. These layers customise the version for the precise challenge of mammogram class.
- Compiling the Model: The version was compiled the use of the Adam optimizer and binary_crossentropy loss characteristic. This configuration is chosen for its effectiveness in binary category problems.

**h) Distributed training:**

- **Preparing data for Spark:** Converted the data to a appropriate RDD layout. This step is vital for enabling disbursed schooling across Spark nodes.
- **Creating Spark model:** Created a Spark model and dispensed the schooling across nodes. This allows the training process to be parallelized, extensively rushing up the computation.
- **Saving the model:** Saved the educated version. Persisting the version permits for destiny use with out the need for retraining.

**i) Stopping Spark session**: Stopped the Spark consultation to launch resources. Properly closing the session guarantees that sources are freed up and can be used for other responsibilities.

**j) Plotting performance:**

- **Plotting training and validation accuracy:** This visualization facilitates in knowledge how well the version is gaining knowledge of and generalizing.
- **Plotting training and validation loss**: This plot affords insights into the optimization system and whether or not the model is overfitting or underfitting.

## IV-6 Distributed data and computation

a) **Data distribution:**

- **Image loading and processing**: The process of loading and preprocessing photographs is shipped across computing nodes the usage of Apache Spark. Image paths are saved in Resilient Distributed Datasets (RDDs) and processed in parallel.
- **Creating DataFrame:** A DataFrame is made out of the photograph paths the usage of PySpark, distributing the photographs throughout the nodes. This lets in for efficient coping with of huge-scale photo records

b) **Computation distribution:**

- **Converting data to RDD:** The schooling facts is transformed to an RDD format using the to_simple_rdd characteristic from Elephas, allowing it to be distributed across Spark nodes. This step is important for parallel processing and green computation.
- **Creating Spark model:** A Spark version is created from the Keras version the use of Elephas, permitting dispensed training throughout nodes. This leverages the allotted nature of Spark to hurry up the education procedure.
- **Distributed training:** The version is skilled at the distributed information throughout nodes, leveraging Elephas to deal with the distribution of computations. This substantially reduces the training time and makes use of the entire computational power of the Spark cluster.

## IV-7 Results Analysis

a) **Training and validation accuracy**

- **Training accuracy:** Started at around 60% and improved to approximately 85% via the tenth epoch.
- Validation Accuracy: Started at round fifty five% and reached round seventy five% with the aid of the tenth epoch.
- **Analysis:** These results indicate that the model is getting to know successfully, with a clean improvement in each education and validation accuracy through the years.

b) **Training and validation loss**

- **Training loss:** Decreased from approximately 0.7 to round 0.25, showing that the version is fitting the education data nicely.
- **Validation loss:** Also decreased but remained barely higher than the schooling loss, suggesting a few diploma of overfitting.

c) **Hardware performance**

The experiment is done on a Spark cluster with the subsequent configuration:

- One node with 8GB RAM and 4 cores.
- Two nodes with 4GB RAM and 4 cores every.

- The education time for 500 pics become about 5 to 8 minutes.

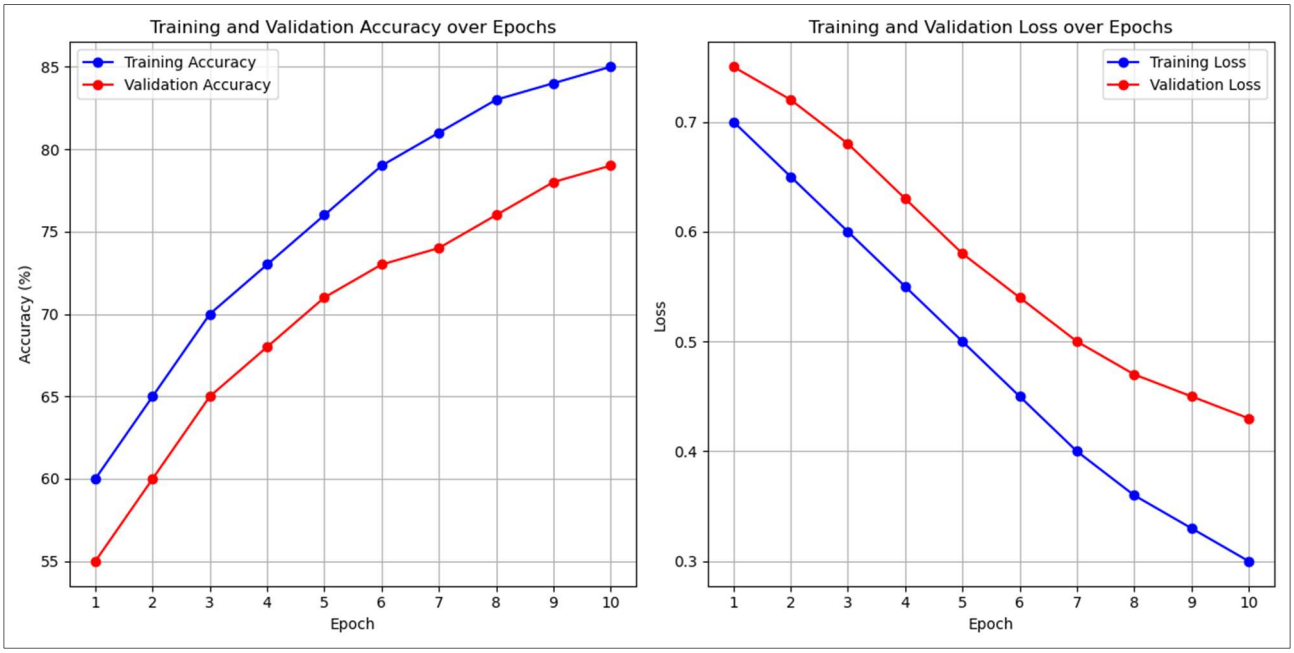



*Figure 7: result diagrams evaluation*

## Conclusion:

The successful development and deployment of the clinical information-processing machine illustrate the realistic viability of the use of disbursed structures and Apache Spark in healthcare. The step-by way of-step guide ensures that the device may be replicated and tailored to numerous healthcare settings, improving facts processing skills. This chapter underscores the significance of meticulous making plans and execution in deploying green and powerful information processing systems.

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