Big Data Technology Architecture Proposal for Smart Agriculture for Moroccan Fish Farming

SARAH BENJELLOUN, MOHAMED EL MEHDI EL AISSI,
YOUNES LAKHRISSI, SAFAE EL HAJ BEN ALI
University of Sidi Mohamed Ben Abdellah Fes,
MOROCCO

Abstract: - As the global population increases rapidly, so does the need for fishing products. Aquaculture is well-developed in Asian countries but is underdeveloped in countries that share Morocco's climate. To meet the rising demands for aquaculture production, it is vital to embrace new digital strategies to manage the massive amount of data generated by the aquaculture environment. By employing Big Data methodologies, aquaculture activity is handled more effectively, resulting in increased production and decreased waste. This phase enables fish farmers and academics to obtain valuable data, increasing their productivity. Although Big Data approaches provide numerous benefits, they have yet to be substantially implemented in agriculture, particularly in fish farming. Numerous research projects investigate the use of Big Data in agriculture, but only some offer light on the applicability of these technologies to fish farming. In addition, no research has yet been undertaken for the Moroccan use case. This study aims to demonstrate the significance of investing in aquaculture powered by Big Data. This study provides data on the situation of aquaculture in Morocco in order to identify areas for improvement. The paper then describes the adoption of Big Data technology to intelligent fish farming and proposes a dedicated architecture to address the feasibility of the solution. In addition, methodologies for data collecting, data processing, and analytics are highlighted. This article illuminates the possibilities of Big Data in the aquaculture business. It demonstrates the technological and functional necessity of incorporating Big Data into traditional fish farming methods. Following this, a concept for an intelligent fish farming system based on Big Data technology is presented.

Keywords: - Data-driven Fish Farming, Big Data Management, Data Lake, Data Processing, Data Insights, Smart Aquaculture.

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1 Introduction

All spheres of endeavor have experienced substantial progress thanks to the growth of robotics, the Internet of Things (IoT), fifth-generation (5G), Big Data, and artificial intelligence, [1]. These technologies accelerate the emergence of intelligent industries. Agriculture is the world's most crucial industry, [2]. The demand for food increases along with the global population, [3]. Fish is a form of protein that is leaner and lower in calories. Consequently, fish are extensively consumed, [4].

The contribution of aquaculture to global food safety is essential. In recent years, aquaculture production has been expanding all around the world. According to The World Bank, fish production climbed in fifty years from 1 million tons in the 50s to 55 million tons in 2004 to 90 million tons in 2012 and reached 106 million tons in 2015, [5]. Regarding fish output, Asia ranks first, with China as the most significant aquaculture producer, followed by Indonesia, India, Vietnam, the Philippines, Bangladesh, South Korea, Thailand, and Japan. Unfortunately, Morocco needs to improve its performance in this area. Aquaculture in Africa, in general, is limited despite huge prospects, [6]. Morocco is our research location since it is the country of residence and affords contact convenience.

Big Data offers tremendous promise for evaluating agricultural and aquacultural productivity-enhancing interventions. Indeed, all industries have benefited greatly from the advantages of data-oriented solution and their implementations. According to [7], in 2019, the total of data analysis and business development reached 189.1 billion US dollars; in 2022, this amount is estimated to be 274.3 billion US dollars. These statistics urge the adoption of data solutions to achieve their benefits. Adopting Data-oriented solutions in fish farming permits intelligent management and smart decision-making. Big Data solutions aid sectors and businesses in decision-making by handling and analyzing massive amounts of data. Diverse organizations invest in Big Data technologies to uncover hidden patterns, market trends, client preferences, and unidentified linkages.

Big Data solutions have been applied in numerous areas, such as banking, insurance, medicine, industry, and marketing. Even though Big Data has gained much success in the stated disciplines, it began being adopted in agriculture only lately, even though not in the fish farming domain, [8]. Agriculture was the first industry to benefit from Big Data-related technology [10], followed by a few aquaculture commercial solutions. Based on agriculture specialists' feedback, adopting Big Data to fish farming could enhance profits and the quality of products, [9].

For this significant purpose, implementing new Big Data approaches has become vital to face the difficulties of productivity, environmental impact, food security, and sustainability. The inspiration for producing this paper originates from the fact that Big Data is a relatively new approach underutilized in fish farming despite its proven benefits in other fields.

The primary objective of this contribution is to demonstrate how Big Data can overcome obstacles in fish farming by providing a Big Data Architecture for fish farming systems.

In this regard, the current research intends to offer a functional architecture and expand it to a Big Data-based technical architecture. This effort aims to develop a system that not only manages but also optimizes the production of fish by utilizing already-existing data. The idea is initially to get data, process it, and store it before employing it for reports, dashboards, and predictive purposes.

This report provides data on the current situation of aquaculture in Morocco to demonstrate the need for improvements in this field. Then, we illustrate the various applications of Big Data in this sector by analyzing research publications on data-driven investigations. Then, we concentrate on the various Big Data strategies that have the potential to improve fish farming production. Finally, both functional and technological architecture proposals are presented.

The structure of this work consists of seven primary components. The first section outlines the condition of aquaculture in Morocco. The following part describes the procedure we took to conduct the research. In the third section, we stress use cases of Big Data connected to fish farming. The three key use cases are management, optimization, and prediction. The fourth segment offers Big Data approaches for Fish Farming. In the fifth section, we propose a functional architecture for Big Data for the fish farming use case. The sixth section outlines each component of a dedicated technical architecture proposal. The seventh section comprises works that are linked.

2 Aquaculture in Morocco

Aquaculture in Morocco continues to expand at a reasonably modest rate compared to other locations worldwide. Currently, Asian countries produce the highest amounts of aquaculture products. According to The World Bank [11], Morocco's continental aquaculture production climbed from 1,403 tons in 2001 to 2,250 tons in 2005. The production level decreased to 579 tons in 2008 before rising to 1,267 tons in 2018. (figure 1).

According to [12], annual aquaculture production has reached 13,000 tons, mainly from reservoirs, lakes, and rivers. The residual production of continental aquaculture in 2018 is distributed as follows:

- Eel (estimated production level of 350 tons/year),
- Tilapia (about 200 tons/year),
- Trout (100 tons/year),
- An unspecified amount of production from reservoir fisheries of carp and other species.

Therefore, it produced a total of 14,267 tons of fish in 2018, and according to Our World in Data, the per capita consumption of fish and seafood in Morocco was 19.47 kilograms, for a total of 692,742,6 tons.

Given the limited production, it cannot be denied that the aquaculture industry in Morocco is still in its infancy. In addition, according to the International Trade Center's (ITC) Trade Map [13], the value of Morocco's fish imports is 216 032 million US dollars.

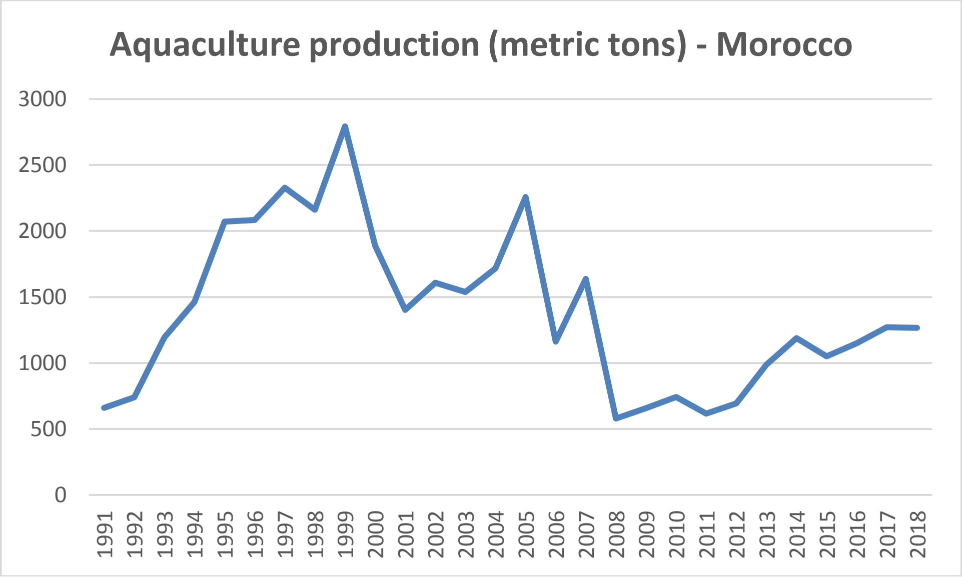

Fig. 1: Moroccan Aquaculture production (metric tons) 1991-2018, [11].

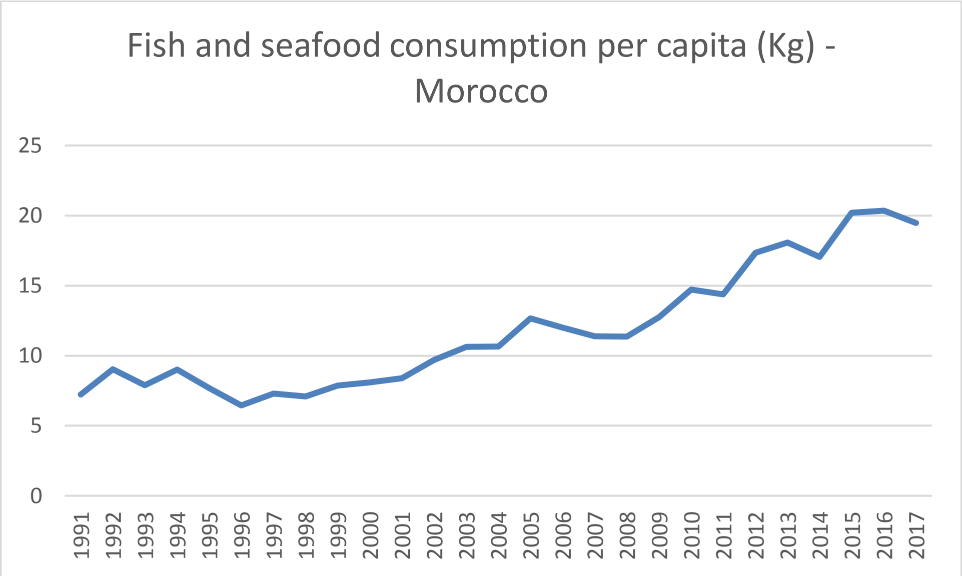

Fig. 2: Moroccan consumption of Fisheries per capita 1991-2017, [14].

In addition, the fish and seafood consumption per capita in Morocco in 2017 was 19.47kg, which equates to a total of 692,742.6 tons of fish and seafood consumed in Morocco (figure 2).

When comparing the fish production (14.267 tons) and fish consumption (692,742,6 tons), a significant deficit must be closed over time, necessitating the importation of fish products. In order to meet the rising demand, it is necessary to replace traditional fish farming systems with intelligent fish farming systems. The primary purpose of this work is to reveal the potential of Big Data Technology and how it might transform the quality and management of fish production through a data-driven fish farming system.

3 Methodology

To conduct the study, we explored existing methodologies using a conventional approach. All available literature released after 2015 has been evaluated. In addition to the period criterion, we employed two inclusion criteria: publishing the complete paper and relevance to the research. In addition, two exclusion criteria were utilized: English-language language publications and articles focusing on technical design. We used the following query to retrieve articles from updated research databases such as Web of Science, Springer, and IEEE Xplore: ["Big Data" OR "Data-driven" OR "Big Data Technologies" OR "Data Lake Architecture"] AND ["Aquaculture" OR

"Fish Farming"] AND "Morocco."

Unfortunately, no publications about Smart fish farming utilizing Big Data in Morocco could be identified. Instead, we found the majority of publications on Asia and specifically used China. In order to solve this difficulty of insufficient references, we based our research on articles from countries with climates nearly identical to Spain. In addition to Spain, no pertinent publications from Algeria or Tunisia were discovered.

After gathering the articles, our methodology consisted of the subsequent steps: All relevant Big Data-based aquaculture papers were gathered; since Asia is the leader in aquaculture production, articles from China were selected to examine the various methodologies employed in this region. We limited our research by focusing on applying certain techniques in Spain, which shares a climate with Morocco.

4 Big Data in Smart Fish Farming Use Cases

Big Data is one of the pillars of the 4.0 industry, and it has been adopted in numerous industries, including those in the following: healthcare, manufacturing, entertainment, cyber security and intelligence, crime prediction and prevention, science, traffic optimization, and weather forecasting. Big Data gives firms invaluable insights and undeniable profits, [15], [16].

As smart technologies and sensors proliferate on farms and the quantity and scope of farm data expand, farming processes will become increasingly data-driven and data-enabled. Rapid Internet of Things and Cloud Computing advances drive the Smart Farming phenomena, [17].

These technologies can be utilized in fish farming to forecast patterns, boost productivity and profitability, and enhance fish quality. Some researchers are interested in Big Data for its potential to contribute to the sustainability of aquaculture, [18], [8].

Fish farms continuously generate and gather data [19]. The aquaculture data value chain begins with data acquisition from either streaming or batch data sources [20]. Preprocessing is used to sanitize collected data for validation reasons. This data is subsequently stored in a distributed storage system so that Data Analysis can be performed, [15]. There are four distinct Data Analysis categories:

- Descriptive Analysis: Utilize dashboards to track Key Performance Indicators (KPIs);
- Diagnostic Analysis: Apply drill-down of descriptive analysis to identify patterns of behavior;
- Predictive Analysis: Use statistical modeling to forecast what is most likely to occur;
- Prescriptive Analysis: Use the learnings from all prior analyses to decide what actions to take.

Data Visualization is the graphical depiction of data, which may be utilized to monitor IoT devices' production and activity status using data supplied by these devices.

Incorporating Big Data technology into fish farms aims to improve production per cost quota and environmental footprint by enhancing fish survival and water quality for greater sustainability, [19], [21]. Growth, survival, and feed conversion ratio (FCR) are aquaculture's most economically essential qualities, [22]. Numerous articles examine these issues to comprehend the circumstances that influence these three characteristics.

As China is the global leader in the aquaculture industry, numerous research articles utilize Big Data to examine aquaculture. Relevant applications discovered can be categorized into six groups [23]: live fish identification, species classification, behavioral analysis, feeding decisions, size or biomass calculation, and water quality prediction. In addition to focusing on economic factors, preserving an ecological environment with high water quality is believed to be the most crucial factor in ensuring production efficiency with high quality, [24]. Consequently, significant research has been undertaken in water quality management utilizing Big Data applications, [24], [25], [26], [27], [28]. Comparatively, Spain's research publications focus on fish feeding strategies and tanks' water quality management for enhancing the operational process' economic efficiency, [29], [30], [31].

5 Big Data Techniques for Smart Fish Farming

Technology is one of the effective ways to boost agricultural productivity in terms of quality and quantity. Big data technology and practices effectively enhance agricultural production and tackle future difficulties. In general, two concepts of database management systems can be distinguished.

5.1 Data Warehouse

The Datawarehouse architecture uses a relational database to allow data analysis and reporting. Typically, it consists of structured historical data from transactional databases, [32]. In addition, using the data warehouse concept, a subject-oriented approach is adopted to store the data, meaning that each table is constructed to precisely meet a previously determined need. Moreover, before saving data in the landing zone of a DWH, it must adhere to a specific structure. In other terms, it may undergo data cleansing operations to ensure excellent data quality for reporting, [33].

In smart fish farming, data and information are the fundamental components. The collection and sophisticated analytics of all or a portion of the data will enable decision-making grounded in science. Nonetheless, the vast quantity of data in smart fish farming presents numerous obstacles, including different sources, varied formats, and complex data, [34].

Information about the devices, the fish and its milieu, and the breeding process are available from numerous sources in various formats such as pictures, audio, and text files. The complexity of the data stems from the various species, modes, and cultivation phases. Managing those mentioned above massive, nonlinear, and high-dimensional data is a challenging undertaking. In addition, the ETL (Extract, Transform, Load) is the approach to collecting data in a data warehouse architecture.

The extraction step represents extracting heterogeneous/homogeneous data from the source; the second step is transforming data into an appropriate form and cleaning it to make querying and analysis more efficient. Data loading refers to storing data in the target.

5.2 Data Lake

The data lake architecture is characterized as a robust data infrastructure for storing enormous quantities of data, characterized by its variety. In addition, it offers to store each data type in its raw format, despite its origin, [35].

The Data Lake provides a high degree of flexibility since the captured data is schema-less; all the data can be stored regardless of the design or the requirement to know the future use case and where our acquired data should deliver answers, [36]. This architecture provides excellent flexibility when analyzing data through a querying language, Data analytics, full-text searching, real-time analytics, and machine learning.

In a data lake, we refer to an ELT (Extract, Transform, and Load) process rather than an ETL (Extract, Transform, and Load), which is the fundamental data-acquiring method for the data warehouses. In this perspective, a data lake architecture's priority is collecting and storing data in its file system to constitute a solid historical database, [33]. After that, the transformation phase is where we apply the preprocessing of data to build data suitable for each use case.

In the following table (table 1), we present a comparative overview between the Data Lake architecture and the Data warehouse architecture:

Table 1. Data Warehouse versus Data Lake.

Characteristics	**Data Warehouse**	**Data Lake**
Data	Relational from Transactional systems and operational databases	Relational/non-relational from IoT devices, social media
Schema	On-write	On-read
Users	Business Analysts	Data Scientists, Data Engineers and Business Analysts.
Analytics	Batch reporting, B.I., and visualization	Machine Learning, Predictive analytics, data discovery, and profiling

To choose the appropriate architecture, it is essential to note that the collected fish farming data differs from the data previously kept in standard database management systems because it consists of huge amounts of data.

In addition, we must determine if the data created by fish farms can be categorized as Big Data in order to select the most appropriate architecture for data management. Due to its qualities, this information may not qualify as Big Data. Nevertheless, some researchers believe it to be Big Data and note that it will be Big Data if all data from the fish farming system are compiled, [8], [36]. The following section describes the properties of fish farm data that come inside the 5 Vs of Big Data, [37].

- Volume: Fish data is often produced by various devices, including tanks, pumps, manual measurements, and sensors, [38]. Usually, workplace PCs or even cloud services are used to store this data. According to statistics, fish farming systems produce and retain enormous volumes of data organized by particular years. Because of this, it can be challenging to transfer large amounts of data to other devices.
- Velocity: Velocity represents the rapid changes in data characteristics. The average hourly data output from various sensors is 10 MB. The data size keeps growing depending on the actions involved in fish production, [39]. As a result, data size grows when fish output is at its peak but continues even when production is low. Fish have different lifespans that vary from one to the next. As a result, fish data differ from one another.
- Variety: Variety is the different types of data from multiple sources. The variety is wide when data is structured, semi-structured, and unstructured. Data from fish farms should be organized based on where it came from to comprehend better and utilize the information. Data can occasionally differ from device to device, from an automatic sensor to a human technique, [39], [40]. Data should be managed appropriately according to its collection, types, and procedures. It is crucial to appropriately input manual data into the computer and integrate it with machine-based sensors, [41]. It is necessary to analyze and organize the manually gathered data into a structured format for later usage.
- Veracity: In fish farming, manually generated data generally is unstructured, [41]. The quality of the data is also an issue. Manually obtained data are typically noisier than data from machine-based sensors, [42]. Additionally, sensor elements and human factors significantly impact fish farming data. These influences can be reduced by keeping accurate records of manually applied inputs and adding automated sensors to monitor closely.
- Value: Aquaculture data usually bears a high volume of information generated by every stage, [43]. It also offers a lot of potential and worth for judgments in the future, [44]. Sensors, APIs, post-production research, and environmental elements are frequently used as data sources, [45]. It is extremely valuable at various phases of fish production for information on water pH, nutrient content, feed content, humidity, required temperature, illnesses, and other important details, [46].

The claims mentioned above make it abundantly evident that fish farming data should be deemed Big Data in all respects and qualities, necessitating the adoption of the Data Lake architecture. The usage of fish farming Big Data by agriculturists, fish farmers, researchers, academicians, and decision-makers will determine its potential.

6 Functional Architecture Proposal based on the Data Lake

The functional architecture based on a Data Lake has evolved from mono-zone to multi-zone, depending on the technical need.

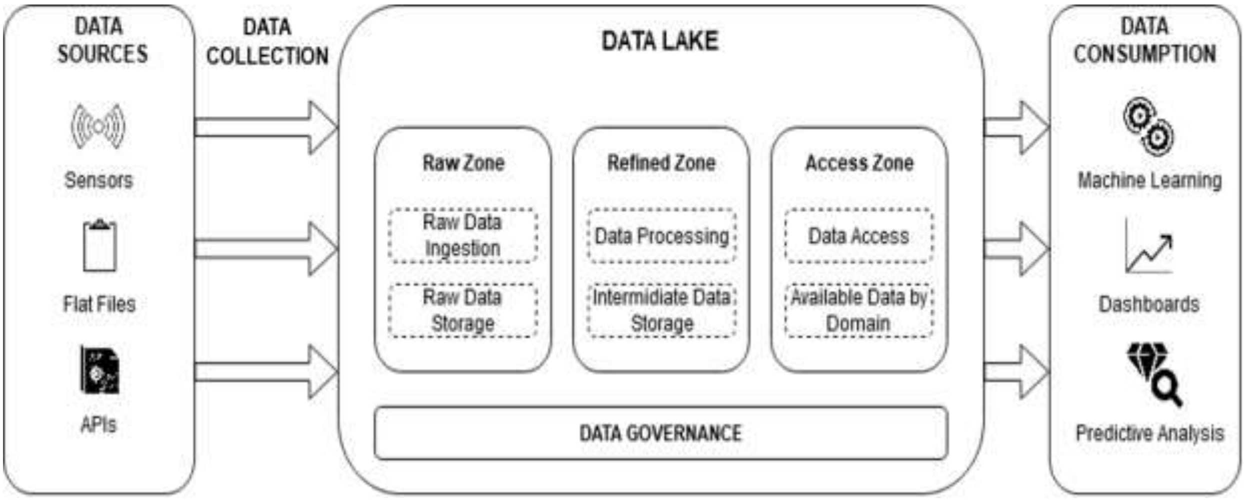

Fig. 3: Functional architecture proposal for Data-driven fish farming system

The Data Lake architecture is designed to support the storage of all structured, semi-structured, and unstructured data flowing from the sources. As a result, the mono-zone Data Lake stores data in its raw format efficiently.

However, in most circumstances, we may make specific changes to the stored data at the Data Lake level. Under these conditions, we began utilizing the multi-zone Data Lakes by establishing multiple data storage levels. This strategy will permit us to manage data more effectively. As illustrated in Figure 3, our suggested Data Lake architecture for the fish farming context consists of three data storage levels.

6.1 Data Sources

There might be numerous data sources in fish farming systems, each with its unique data format. Our system's primary data source is IoT devices that capture streaming data of water parameters such as Pressure, Temperature, pH, Humidity, Dissolved Oxygen, or salinity. The following data source consists of data generated manually by company personnel as CSV or text files. This data source includes marketing data and measurement data that sensors still need to automate. APIs provide data on the weather, the global average price of fish, and statistics about fish farming marketplaces.

6.2 Data Lake

The Data Lake architecture features three levels of data storage. The raw zone is the first level of data storage, which includes source data without any alterations. The data can be ingested in real-time or in batches. This Data Lake Zone offers the data engineers the ability to find the original data version.

In the Refined Zone, data can be transformed based on requirements, and intermediate data can be stored. In the Refined Zone, there are two data processing types: batch-based and stream-based.

The Access Zone is the level where data can be explored. This level enables self-service data consumption for Reporting, Business Intelligence, machine learning algorithms, and statistical analysis.

The Data Governance Zone encompasses all previous Data Lake Zones to assure data quality, metadata management, and data accessibility.

6.3 Data Consumption

The data can be consumed in various ways, including Data Visualization via dashboards displaying KPIs (Key Performance Indicators) for each use case, predictive analysis via Machine Learning algorithms, and statistical analysis.

7 Technical Architecture Proposal using Big Data Technologies

In order to demonstrate the necessity for Big Data in a fish farming system, we offer a technical architecture capable of managing the data flows generated by normal fish farming activities. In this architecture, there are three distinct phases (Figure 4):

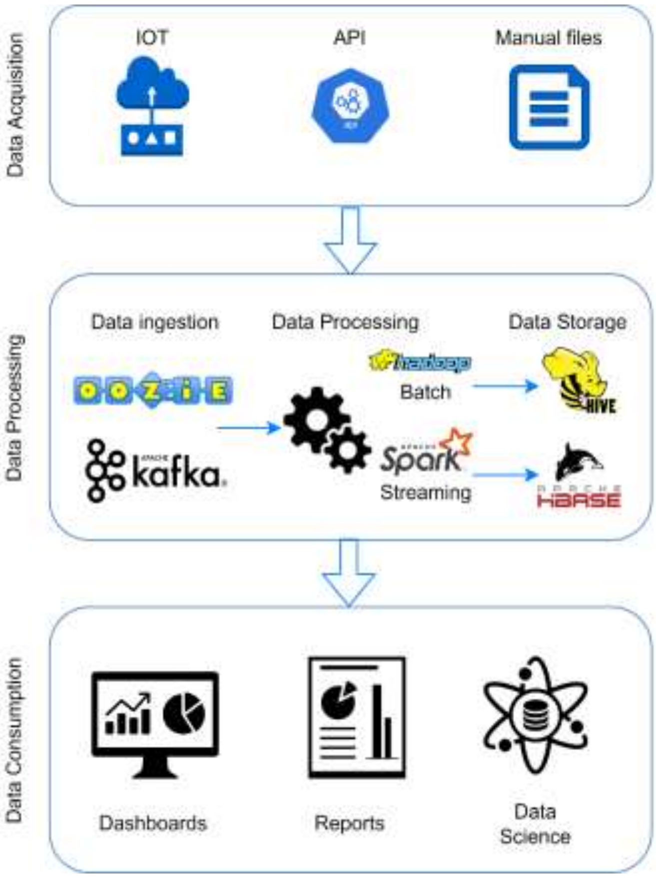

Fig. 4: Data Management Process with Detailed Technologies

7.1 Data Acquisition

Technical architecture is a specific set of rules and interactions of the system's components or features that ensure the system meets a defined aim and a set of requirements. For this reason, we suggested a technical architecture based on Big Data technologies that enable intelligent fish farming systems.

The design of fish farming creates three sorts of data. Sensors generate a vast amount of data, which must be processed before usage. Since there are numerous devices, it is necessary to translate or standardize data into a single format. The sensors communicate with the cloud to transmit data using HTTP/HTTPS or MQTT protocols. The data focuses on temperature, light, chemical composition, and average fish weight, [46].

Complementary data is hand-written in CSV format and provided through email in flat files. The files are received and transmitted to the Data Lake cluster by a data bot, which is a type of mail bot. Manual data may include the amount of food per tank or the number of fish. All external data on the weather, fish prices, fish food prices, and others are contained within API data. It is retrieved from APIs using shell scripts and stored in flat files in preparation for consumption.

7.2 Data Ingestion / Processing

Before data storage, analysis, and access, data intake collects and delivers data to the processing system. Based on the type of data, two tools can be distinguished:

- Apache Oozie is utilized for process orchestration. It is used to construct and schedule data jobs at specific dates, times, or frequencies. Long-running jobs are used to store flat files from emails and APIs in the Hadoop cluster, [45]. These activities are scheduled regularly to ensure that dashboards and reports utilize the most recent data.
- Apache Kafka is responsible for reading and retrieving the sensor-generated and publishing streaming data to the OPC server, [45].

Hive tables containing batch data from APIs and manually fetched data are uploaded to the Data Lake via Oozie. Apache Spark reads, transforms, and stores data in additional Hive or Apache HBase tables.

7.3 Data Consumption

After the data have been prepared comes the data exposition step. Depending on the use case, data is presented through dashboards using data visualization tools, or we use machine learning algorithms and statistical analysis to explore and uncover hidden patterns and correlations, [47], [48]. All this is to allow businesspeople, namely fish farmers and researchers, easy access to valuable information, [49].

8 Related Works

Existing research articles are primarily concerned with agriculture and extracting useful information from collected data. In their research, Lytos et al. describe agriculture as a complex scientific topic that necessitates a particular infrastructure for managing and interpreting incoming data.

In addition, they gave a comparison of numerous frameworks used to manage agricultural data. However, only two of the fourteen frameworks enable Big Data. Indeed, a specific Big Data architecture is essential because it enables the incorporation of IoT, enabling efficient data collection via sensors and automation of several tasks, [9].

In parallel, N.N.Misra et al. showed in their research that since implementing IoT solutions in agriculture, it has been creating vast volumes of data, classified as "Big Data," which may provide new options for monitoring agriculture and food operations. They discussed how Big Data, IoT, and AI could be combined to determine the future of agri-food systems. This study focuses primarily on agricultural analyses. It focuses on how AI can monitor greenhouses and how Supply Chain modernization can improve food quality, [50]. However, they should have discussed how Big Data approaches contribute to the development of the fish farming area through IoT integration.

In addition, Xinting Yang et al. highlighted in their research study how Deep Learning (DL) might be applied to smart fish farming to address various data processing difficulties. In addition, he asserted that the most important contribution of DL is its capacity to extract characteristics automatically, [22]. Moreover, before we begin applying DL to this data, we must be able to control it, especially when discussing the IoT-generated enormous data from fish farming. Creating a specialized Data Lake architecture is the best way to overcome this scenario so that data may be more efficiently managed and consumed.

9 Conclusion and Future Work

These days, Big Data methods are used in practically every business, from finance and banking to manufacturing and advertising to even medical. In addition, its efficacy has been demonstrated by its contribution to enhancing conventional operational procedures and increasing revenue. Incorporating this technology into fish farming is a crucial aspect of boosting fish farming production to meet the expanding global population's high food demand. However, Big Data is not frequently used in agriculture or aquaculture in particular. Big Data tools are the cornerstone of transforming conventional fish farming into modern, intelligent, digital fish farming. It solves the restrictions associated with fish farming systems by examining farmers' demands, market needs, financial efficiency, and the viewpoints of other stakeholders.

This study focuses on fish farming in Morocco since it reveals a substantial disparity between fish output and market demand, which results in a substantial quantity of fish imports. This paper emphasizes the need for Big Data integration in aquaculture and subsequently proposes a Data Lake architecture tailored to the aquaculture use case.

We propose a functional architecture of fish farming systems consisting of three steps, beginning with data sources, moving through the Data Lake solution, and concluding with data consumption to ensure the efficient utilization of generated fish farming data. The data source level consists of sensor-generated streaming data, flat files providing additional operational data, and API data. The Data Lake stage includes a raw zone, a refined zone, an access zone, and data governance for data accessibility, usability, integrity, and security. The final layer, data consumption, is responsible for data analysis and visualization.

The previously proposed functional architecture is extended and used to propose a technical architecture. The proposed technical architecture relies on three phases: data acquisition, processing, and consumption. We detailed each phase and specified its different technologies and tools, guaranteeing efficient data handling.

This work's contribution resides mainly in proposing a functional architecture to exploit the data generated naturally by fish farms to generate value through increased productivity and decreased waste and fish mortality. Then, by proposing a technical architecture on top of the functional architecture, we show the feasibility of this proposal using specific technologies.

Following the proposal of the technical architecture of the data-driven fish farming system, our future work will focus on utilizing the proposed Data Lake architecture as a foundation for an advanced study employing various forms of data analysis, such as artificial intelligence and machine learning.

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