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INTEGRATION OF IOT-ENABLED TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE IN DIVERSE DOMAINS: RECENT ADVANCEMENTS AND FUTURE TRENDS

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ABSTRACT

The concept of the Internet of Things (IoT) has risen as a revolutionary innovation, establishing a connection between the physical and digital worlds and significantly impacting various aspects of daily life. In the healthcare field, it has unlocked the potential of connected medical devices, enhancing care through real-time patient monitoring and the effective management of chronic diseases. Within the industry, IoT facilitates predictive maintenance, optimizes manufacturing processes, oversees the supply chain, and monitors assets. Smart cities utilize IoT to elevate infrastructure management, enhance security, and promote sustainability. In agriculture, IoT sensors bring about a transformation in precision farming, optimizing resource utilization, and increasing yields. Smart homes integrate IoT for home automation solutions, empowering homeowners to remotely control devices and systems. Finally, in the transportation, IoT is at the forefront of revolutionizing connected and autonomous vehicles, providing advanced features in safety, navigation, and onboard entertainment. The integration of (IoT) and (AI) yields considerable benefits across various sectors by enhancing operational efficiency, facilitating informed decision-making, and fostering the creation of smarter, interconnected environments. In this article, we conducted a bibliometric study focused on industrial sectors related to the Internet of Things (IoT) from 2018 to 2023. Our analysis centers on comparing the most frequently explored domains, highlighting their popularity and performance. Furthermore, we examined currently predominant and beneficial technologies, particularly those aimed at optimizing operations, improving efficiency, and reducing costs.

Keywords: *IOT, AI, AIOT, IIOT, Agriculture, Aquaculture, Healthcare, Transportation, Smart Homes, Smart Cities, Real-Time Monitoring, Sustainability.*

1. INTRODUCTION

The Internet of Things (IoT) is a network comprising interconnected computer devices, objects, digital and mechanical equipment, animals, and people, each equipped with distinct markers. It facilitates the exchange of information within a network without necessitating direct communication or human-computer interaction [1].

The field of IoT has in recent times garnered significant interest owing to its applicability in various fields. This range of applications has generated a multitude of requirements that IoT systems must adapt to. These requirements have evolved significantly, necessitating the design of systems with varying levels of complexity and performance expectations. This situation has greatly influenced its architecture, which consists of four interconnected layers, as depicted in Figure 1 [2]. The first layer, known as the sensor layer, forms the foundation of the IoT architecture. It comprises sensor networks, embedded systems, RFID tags, readers, and additional types of sensors situated in the field. Each of these sensors serves the functions of identification, information storage, and data collection. The next layer, the gateways and network layer, is tasked with transferring the data collected by the sensors to the upper layer. It must be compatible with standardized protocols, flexible, and scalable to support different types of sensors. This layer must be high-performing and ensure a robust network while enabling different organizations to communicate independently. The management service layer serves as a bidirectional interface between the gateway layer and the application layer. It manages devices and data by capturing large amounts of raw data and extracting relevant information from the stored data while ensuring the security and confidentiality of the information. Finally, the application layer constitutes the top layer of the IoT. It provides a user interface that allows various users to access different applications that can be utilized in diverse sectors, including transportation, healthcare, agriculture, supply chain, government, retail, and more [3].

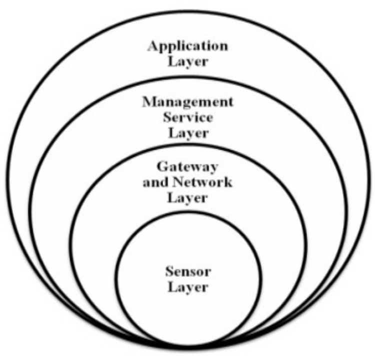

Figure1: The architecture of IoT

The multifaceted technology known as the IoT spans a wide range of applications across various sectors, including agriculture, healthcare, smart homes, smart cities, and transportation. In agriculture, it is applied to oversee and enhance environmental conditions, crop management, and livestock tracking. Within healthcare, IoT offers solutions such as monitoring patients from a distance, medication management, and the tracking of connected medical devices. In smart homes, this technology enables the automated control of devices, energy management, and home security. In smart cities, IoT contributes to efficiently managing urban resources, monitoring air quality and waste management, and implementing intelligent transportation systems. In transportation, IoT provides benefits such as real-time vehicle tracking, traffic management, and road safety. Its adaptability yields advantages ranging from operational efficiency to the improvement of quality of life. By facilitating advanced connectivity, real-time data collection, and thorough analysis, it plays a crucial role in optimizing processes, supporting informed decision-making, and creating more intelligent and sustainable environments.

The merging of (AI) and the (IoT) constitutes a rapidly advancing and transformative field known as AIoT (Artificial Intelligence of Things). This innovative approach empowers devices to collect and analyze data, enhancing decision-making processes that closely emulate human cognition. Currently, the convergence of AI and it seamlessly permeates various facets of our daily lives, encapsulated within the overarching framework of the concept mentioned as the (AIoT). This integration has the potential to revolutionize diverse industries, improve efficiency, and introduce novel applications, marking a significant evolution at the intersection of AI and IoT technologies [4].

The concept of the Industrial Internet of Things (IIoT) is extensively utilized in the industry to describe a digital transformation characterized by the connectivity of essential assets, the application of advanced analytics, and the involvement of contemporary personnel. It relies on a network of interconnected industrial devices through communication technology, establishing systems capable of monitoring, collecting, exchanging, and analyzing crucial information. This data is then utilized to assist businesses in making faster and more informed decisions. It employs smart sensors and actuators to optimize processes within industrial and manufacturing settings [5]. The implementation of it has expanded into various sectors, including cloud computing, data analytics, mobile technology, and others, capitalizing on the growth of sensors and technological advancements [6]. This expansion is grounded on a robust foundation encompassing various technologies, as depicted in Figure 2. These technologies include cloud computing services such as AWS it, Azure IoT, and Google Cloud IoT, used for IoT data storage, analysis, and management. Additionally, the local processing of IoT data on devices (edge computing) is implemented to reduce latency and enhance efficiency. The security of IoT devices is of paramount importance to safeguard against threats, necessitating the application of security technologies like identity management, encryption, and intrusion detection. Data analytics technologies, including ML and AI, are harnessed to extract valuable insights from IoT data. Additionally, the utilization of blockchain technology is implemented to safeguard the security of transactions and data within the industrial IoT. Cyber-Physical Systems (CPS) integrate IoT devices, enabling the use of various sensors and actuators in industrial environments, including manufacturing systems and industrial robots. Moreover, Augmented reality (AR) is employed to assist industrial workers in intricate tasks, such as machine and critical system assembly.

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AR facilitates real-time monitoring of workers and machines, generating alerts to prevent errors. Virtual reality (VR) is also utilized to visualize industrial configurations before implementation, reducing setup times and downtime. VR simulations adhere to open standards to accommodate the diversity of CPS and IIoT systems [7].

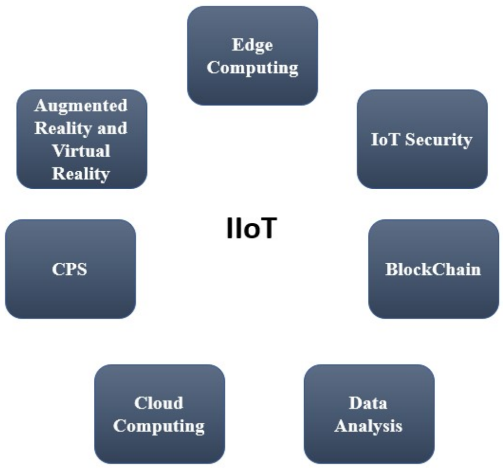

Figure 2: IIoT Technologies.

Table 1 provides a list of acronyms presented in this article. The following sections adhere to this structure: Section 2 outlines the methodology adopted for conducting this study. Section 3 examines the current state of the Internet of Things (IoT) across various domains, covering the period from 2018 to 2023. Section 4 focuses on the comparison of the latest and most utilized domains, highlighting their popularity as well as the currently most effective and advantageous technologies. Section 5 analyzes our study by comparing it with other literature studies, emphasizing the unique contributions of our research. Section 6 explores critical perspectives surrounding Internet of Things (IoT) and Artificial Intelligence (AI) technologies. Section 7 presents the strengths and weaknesses of our research, providing a balanced assessment. Finally, Section 8 consolidates the essential elements covered in the article.

Table1: Acronyms used in this article.

Acronym	Definitions
IoT	Internet of Things
AI	Artificial Intelligence
IIOT	Industrial Internet of Things
ITS	Intelligent Transportation Systems
ML	Machine Learning
CPS	Cyber-physical systems
CNN	Convolutional Neural Networks
RNN	Recurrent Neural Network
GSS	Ground Station Server
PA	Precision Agriculture
AIOT	Artificial Intelligence of Things
UAV	Unmanned Aerial Vehicle
SPA	Smart Precision Agriculture
DL	Deep Learning
RFID	Radio Frequency Identification
IoVT	Internet of Vehicles things
Federated Learning	Machine learning and artificial intelligence techniques.
ABS	Attribute-Based Signature
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
IBS	Identity-Based Signature

2. PAPER RESEARCH METHODOLOGY

A thorough literature review was conducted using the databases of Scopus, ScienceDirect, IEEE Xplore, and Springer to identify pertinent articles focusing on the integration of IoT in agriculture, health, transportation, smart cities, and smart homes with AI. The research period extended from 2018 to 2023, considering the concentration of research efforts during this timeframe. The search specifically targeted English-language journal articles subjected to a peer-review process in the fields of the Internet of Things (IoT) and Artificial Intelligence (AI) applied to specific sectors. The selection of articles was based on the analysis of titles, abstracts, and keywords. In total, 300 articles were identified in the databases. A meticulous analysis of abstracts was conducted to eliminate works not relevant to the research. After removing duplicates, the final review retained 112 articles for inclusion in the primary analysis. The documentation search process is schematically presented in Figure 3.

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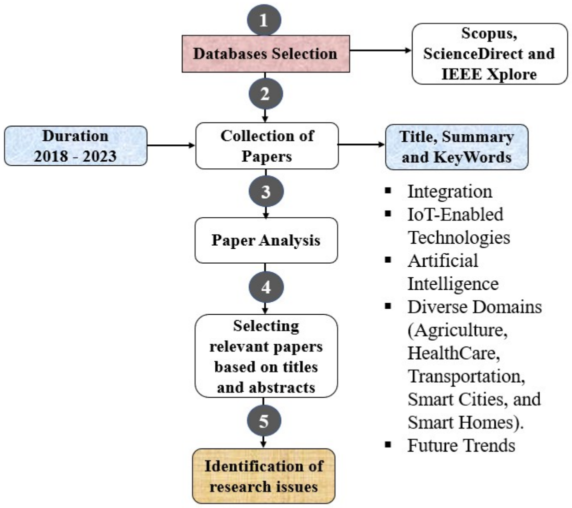

Figure 3: Research methodology.

3. LITERATURE REVIEW

3.1 IoT-Agricultural

The (IoT) is a system of interconnected objects that communicate and share data through the Internet. One of its most significant applications can be found in the domain of smart agriculture, aiming to improve resource utilization while increasing agricultural yields. In an article authored by [8] in 2018, a crop monitoring system based on soil sensors measuring soil moisture, temperature, and humidity was proposed. This system automates irrigation when soil moisture is insufficient, contributing to optimizing water usage. The sensors are connected to a Raspberry Pi, allowing for wireless communication. The results of observations and experimental tests demonstrate that this project provides a comprehensive solution to address issues related to agricultural irrigation. Field implementation could have a significant impact on improving crop yields while reducing water resource wastage.

Aquaculturists currently depend on manual testing to evaluate various water parameters. However, these manual tests are both time-consuming and prone to providing inaccurate results due to the continuous fluctuation of water quality measurement parameters. An alternative preference is the implementation of automated monitoring. In their 2018 study [9], the authors proposed a system for monitoring aquaculture water quality utilizing Raspberry Pi, Arduino, various sensors, smartphone cameras, and Android applications. The monitored water quality parameters encompass temperature, pH, conductivity, and color. The Arduino acquires data from the sensors, while the Raspberry Pi is employed for data processing and acts as a server. Utilizing the smartphone's camera, Raspberry Pi detects water color during photo capture. Android phones serve as remote terminals, allowing aquaculturists to monitor water conditions through the Android application. Comprehensive analyses are conducted to assess the overall state of the water and determine necessary measures. This innovative approach offers improved results at a reduced cost compared to existing systems, enabling aquaculturists to circumvent laborious manual tests. This advancement facilitates increased fish production, thereby contributing to the growing demand for fish.

The LoRaWAN system is designed to meet the needs of agricultural activities that require numerous sensors generating data streams for analysis. In addition to its use in the agricultural sector, research conducted by [10] in 2018 suggests that this system can easily be applied to other social and production processes with similar needs. This cutting-edge agricultural IoT system distinguishes itself through its low energy consumption and exceptional scalability. It utilizes the LoRaWAN network to transmit data efficiently over long distances from sensor nodes for cloud services. The data streams collected by the cloud service system are then utilized for analysis.

Agriculture is a vital sector of the economy, but it faces issues such as inefficient methods, the need for a large workforce, and managing irrigation and fertilizers. The authors of the article [11] in 2018 explored its potential to enhance agricultural efficiency and productivity. It relies on a network of sensors that monitor parameters like soil acidity and temperature. This technology is integrated into traditional farming practices to create smart agriculture. It allows for the collection of environmental data and improves outdated predictions. This approach offers global opportunities to revitalize the agricultural sector by simplifying methods, promoting smart farming, and making farmers' lives easier with minimal effort.

Efficient data transmission technology is vital for real-time agricultural data acquisition. Unlike in industrial applications, data transmission delays in agriculture have a limited impact on production. Wireless communication brings several advantages, including low power consumption, excellent scalability, and reduced costs compared to wired technology. These benefits have spurred the increased deployment of wireless sensor networks for applications such as remote control, automatic irrigation, and environmental monitoring. In a 2019 study [12], the authors investigated various commonly used wireless technologies to develop wireless devices, contributing to the diversification of

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the IoT. Numerous wireless technologies can operate on the same frequency band, like ZigBee, Wi-Fi, and Bluetooth. While Wi-Fi offers high transmission speeds, it consumes a significant amount of power, making it less suitable for low-power sensors. Bluetooth, although secure, has limited range and high-power consumption. ZigBee networks benefit from nodes that can relay data from neighboring nodes, fostering network self-organization. Moreover, ZigBee proves to be cost-effective and energy-efficient, enabling the expansion of the sensor network's reach for the formation of networks over long distances.

The architecture of the (IoT) aims to integrate intelligence into the agricultural domain by combining sensor data, actuators, and farmers. This approach is geared towards enhancing agricultural practices, empowering farmers to administer vital nutrients to crops at precise moments through the ongoing monitoring of agricultural fields. Additionally, user data regarding product demand and costs help ensure the production of high-quality products at reasonable prices. In their 2019 work, the authors [13] base their research on this architecture and also manage real-time food supply chain logistics. Data shared between different entities in the system can generate valuable recommendations for improving agricultural efficiency. The examples cited illustrate that this architecture can be applied to various agricultural scenarios. However, it's crucial to acknowledge certain constraints. These include addressing the storage of extensive volumes of user-generated data, the necessity to formulate intelligent algorithms for swift extraction of pertinent information, and effectively managing the security, privacy, and trust aspects of shared information. Incorporating these features is indispensable to guarantee the efficiency and reliability of the proposed architecture.

In 2019, the authors of this article [14] delved into various automation methodologies, encompassing (IoT), wireless communications, (ML), (AI), and (DL), within the agricultural context. The exploration sheds light on prevalent challenges in the sector, such as crop diseases, suboptimal stock management, pesticide control, weed management, insufficient irrigation, and water management. It suggests that these issues could be effectively tackled through the application of these technologies. The article underscores the significance of addressing concerns related to harmful pesticides, irrigation management, pollution control, and environmental impacts in agricultural practices. Additionally, it outlines the advantages of agricultural automation, including heightened yields and the preservation of soil fertility. Conclusively, the article introduces a proposed system for flower and leaf identification and irrigation using IoT, presenting its potential application in botanical farms.

The use of IoT and AI technologies has the potential to positively transform traditional agriculture. This article by [15], published in 2019, emphasizes the importance of recent computer technologies, particularly AI and IoT, in agriculture, a sector considered crucial for human survival. IoT and AI technologies can enhance agricultural production by integrating with traditional practices. This study explores the application of IoT and AI technologies in Sub-Saharan Africa (SSA) and proposes a technical architecture for IoT and AI to support the development of an SSA platform, establishing an intelligent and sustainable agricultural platform solution.

Smart and efficient agriculture to meet future needs relies on various technologies, with a particular focus on digital technologies. Discussions revolve around communication technologies, including wireless sensors, UAVs (drones), and cloud computing. In a 2019 article authored by [16], a comprehensive review of recent research is provided, along with an exploration of IoT architectures and platforms for agricultural applications. To assist researchers and engineers, the article provides a summary of the existing challenges and upcoming expectations in the industry. Overall, it is clear that every piece of agricultural land is valuable for maximizing agricultural production. However, to fully utilize every inch of land appropriately, the use of sustainable sensor and communication technologies based on the Internet of Things is indispensable.

A system has been implemented to inform farmers about soil nitrogen, phosphorus, and potassium deficiencies via SMS, employing a fuzzy rule-based NPK sensor. In 2020, the authors [17] introduced this Internet of Things (IoT) -based system, introducing an innovative NPK sensor incorporating a Light Dependent Resistor (LDR) and Light Emitting Diodes (LEDs). Fuzzy logic is utilized to detect nutrient deficiencies within the gathered data, employing a set of "if-then" rules based on specific chemical solutions for nitrogen (N), phosphorus (P), and potassium (K). An inference method is used to determine the quantities of N, P, and K in the tested soil, subsequently sending alert messages to respective farmers, specifying the required fertilizer amount at regular intervals. The hardware prototype and embedded software in the microcontroller were

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developed using Python. This model underwent testing on three distinct soil types: desert soil, mountain soil, and red soil. The results highlight the cost-effectiveness of the proposed system.

In 2020, the authors [18] introduced a collaborative framework centered around an intelligent IoT monitoring system tailored for the agricultural sector, with a specific focus on sugarcane production. The goal of the IoT-Agro collaboration model is to offer support to stakeholders, encompassing farmers, factories, and government entities, in the acquisition of data and examination of variations within the sugarcane production process. Real-time updates are conveyed to all stakeholders through a smart application platform. Implementation of this proposed model enables sugarcane production companies to accurately forecast the necessary resource capacity for production. Moreover, the model contributes to the reduction of physical damages, enhancement of moisture traceability, and minimization of resource wastage. The research also intends to verify the efficacy of the proposed collaboration model through the utilization of real-time data in forthcoming studies.

In a 2020 study, the authors introduced [19], an innovative system based on a Multi-Agent System (MAS), deployed using Docker containerization and orchestrated by Kubernetes. Specifically designed for application near a set of pivots in agricultural irrigation fields, the system's core utilizes wireless sensors to gather real-time environmental data for each pivot. This data is then employed to assess and update water requirements every 5 minutes. The system relies on a common weather map to collect measurements for calculating accurate potential evapotranspiration. The calculated value is multiplied by a weighted coefficient (Kc) to determine crop-specific water requirements. The system's proposition is rooted in a collaborative model among multiple agents, enhancing the ability to meet water needs and compensate for potential performance losses or malfunctions of individual sprinklers. Additionally, the system incorporates plant disease and pest recognition, facilitating targeted treatment for the crop through the irrigation pivot. It's noteworthy that this solution can be tailored for drip irrigation, where conventional drones replace camera images, and farmers capture photos themselves.

Integrating the IoT with blockchain technology holds the potential to enhance precision agriculture, elevate farm intelligence, and fortify control over the supply chain network. A 2020 article by [20] delves into how blockchain can effectively address security and difficulties related to performance within IoT-based precision agriculture systems. The synergy between blockchain and IoT is pivotal to the advancement of smart precision agriculture applications. The article introduces novel blockchain models designed to tackle issues within IoT-based agricultural systems. It thoroughly explores the advantages and disadvantages of major blockchain platforms applied in precision farming, spanning food supply chains, livestock grazing, and crop monitoring. The discussion encompasses security and privacy concerns as well as hurdles hindering the progress of blockchain-IoT systems in precision agriculture. The envisioned outcome is a more autonomous, intelligent, efficient, and optimized approach to agricultural management.

In the current context, the concept of precision agriculture, typically associated with traditional farming, is now expanding to aquaponics. This evolution necessitates the adoption of sensing systems (AI), and the (IoT) to effectively monitor and manage automated processes. The fundamental goal of this study is to establish a meaningful connection between the fields of biological and electrical engineering to enhance the sustainability of aquaponics as a viable food source. The authors of [21] 2020, have made a valuable contribution by sharing their technical expertise in automation, IoT, and intelligent systems with aquaponics experts, while simplifying the understanding of automation specialists regarding the specific biological processes in aquaponic systems. This collaboration, focused on expanding aquaponic systems on a larger scale, should accelerate progress in this field and bolster the robustness of commercial solutions, as highlighted in the reference.

In this article, the authors [22], in 2020, proposed a smart agriculture monitoring system that proves to be highly valuable for farmers in need. A GSM modem collects information from the microcontroller and forwards messages to the appropriate contact numbers. The Wi-Fi model sends parameters to an IoT server through a graphical method. Subsequently, the farmer takes necessary precautions for their field. This IoT agricultural monitoring system utilizes wireless sensors to gather data from various locations. These sensors transmit data wirelessly. Powered by an Arduino, the system incorporates temperature sensors, humidity sensors, water level sensors, a PIR motion sensor, and a GSM module. Upon activation, the system conducts real-time checks on water levels, humidity, and humidity rates, sending SMS alerts in case of anomalies. Parameters can be remotely monitored and controlled via the Internet, enabling remote actions through the sensors, a camera, and a microcontroller. The Wi-Fi model transmits

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parameters to the IoT server through a graphical method. This innovation enhances the lives of farmers by providing them with an effective tool for managing their crops and resources.

The imminent transformation of the agricultural industry is anticipated through the applications of IoT, introducing new technologies for monitoring, operations, and the systematic organization of crop and livestock production cycles. Despite the availability of a wide variety of individual IoT systems for agriculture, there is currently no established industrial standard to seamlessly integrate multiple applications. This contribution released in 2020 [23], this contribution introduces a concept for a comprehensive (AI) system spanning the entirety of the agricultural value chain. Operating through interconnected independent AI modules via an extensive cloud network, this innovative approach forms a network that connects users of commercial systems, agricultural technology providers, and computer experts. It has the potential to drive improvements in efficiency and sustainability within the agricultural sector.

In this article, the authors [24], in 2020, investigated the utilization of precision aerial drones in agriculture. Initially, the article provides an overview of Precision Agriculture (PA) and Unmanned Aerial Vehicles (UAVs). Subsequently, they conducted a detailed assessment of the multiple applications of UAVs in crop monitoring and spraying. Furthermore, an evaluation of UAV architecture is undertaken to determine whether it is a single device or multiple UAVs. This evaluation also includes an analysis of the methodology employed, the type of UAV used, its technical specifications, and its payload. The article also delves into the types of crops used in the testing.

In the realm of the IoT, defining big data becomes a complex task as it extends beyond a formal definition. It encompasses not only structured and unstructured data but also involves processes of analysis, information generation, and (automated) decision-making, all unfolding in real-time. A comprehensive review by [25], published in 2020, delved into the significant impact of the (IoT), big data, and (AI) on the transformation of agri-food systems. The review explored how IoT and big data analytics are utilized in agriculture, covering aspects such as greenhouse monitoring, the integration of smart farming machinery, and crop imaging using drones. Moreover, it investigated the influence of these technologies on supply chain modernization, open innovation through social media, sentiment analysis in the food industry, assessment of food product quality through spectral methods, and sensor data fusion. In addition, the review touched on food security by examining genetic sequencing and digital traceability based on blockchain technology. The remarkable advancements in the fields of IoT, big data, and AI have turned once unimaginable achievements into commonplace realities. The adoption and optimal utilization of these technological innovations are crucial for the success of contemporary agriculture and the food industry.

The article authored by [26] in 2021 focuses on greenhouse seedling production based on IoT, which holds significant market value and strict delivery deadlines. The growth rate of seedlings is strongly influenced by the surrounding environment, making it necessary to control IoT-compatible equipment in the greenhouse to meet delivery deadlines and quality standards while reducing energy costs. The proposed system relies on it to connect IoT devices with each other. It employs a hierarchical control process to perform long-term planning at the upper level and hourly operating decisions at the lower level. This system utilizes a crop growth model, intelligent decision-making is based on real-time data collected by IoT sensors, historical monitoring data stored in a database, and real-time data from IoT sensors for greenhouse management.

The 2021 article authored by [27] provides a comprehensive overview of recent research in agriculture, with a specific focus on digital technology. The primary objective is to identify the key applications of agricultural engineering involving artificial intelligence and the Internet of Things. In conducting this analysis, the authors employed scientific databases such as PubMed, Web of Science, and Scopus to review research conducted in these domains over the past decade. The article's conclusions highlight the progression of agriculture digitization using AI and information technology, transitioning from its initial conceptual stage to the execution phase. Furthermore, the article delves into the technical intricacies of artificial intelligence and the Internet of Things, addressing the barriers to the adoption of these digital technologies. This information is crucial for gaining insights into how digital technologies can be seamlessly integrated into agricultural practices, thereby facilitating the implementation of AI and IoT-based solutions in the agricultural sector.

The study conducted by the authors in 2021 [28], presents the development of an aquaponic system based on the (IoT), aiming for interoperability, security, scalability, cost-effectiveness, automation, and flexibility. This innovative system merges

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aquaculture and hydroponics to enhance the well-being of fish, bacteria, and plants. Through a monitoring system equipped with sensors, various parameters like pH, light, water temperature, water level, ammonia, and electrical conductivity are continuously tracked in the aquaponic environment. The Grove expansion board, serving as an extension board linking sensors to the NodeMCU, facilitates the utilization of the MQTT messaging protocol. Integration with Home Assistant and the open-source home automation platform (OpenHAB) allows for comprehensive monitoring, control, and correlation of these parameters through the synergy of the (IoT) and (AI). This solution provides an inclusive, secure, scalable, cost-effective, autonomous, flexible, reliable, and versatile IoT solution tailored specifically for aquaponics.

The 2021 publication by [29], contributes to advancing our understanding by elucidating the obstacles in the domain of smart agriculture. These challenges encompass various aspects, including the computing power of IoT devices, early disease detection through AI, crop water stress monitoring, soil condition assessment, livestock disease tracking, and understanding behavior patterns in agriculture. An intelligent IoT-based system has the potential to reduce food wastage, increase production, and provide valuable insights within the agricultural sector.

The research team has developed an intelligent management system for cage culture operations by combining (AI) and the (IoT). The goal of this study, conducted by [30] in 2021, is to address major issues while promoting large-scale cage culture development. The system collects data from the cultivated domain and transfers it to a Cloud data platform, where this information and the results of big data analysis are applied to cage culture. This intelligent management, successfully combining AI and IoT, is illustrated through examples of underwater biological analysis and AI-powered feeding. The system enables continuous data collection regarding fish health, survival rates, and food residues. The research findings enable aquaculture operators to efficiently reduce food waste, track fish growth, and boost fish survival rates, ultimately enhancing feed efficiency.

Agriculture, including aquaculture, has recently undergone a significant technological evolution due to the progress in (IoT) and (AI). The system presented in this article by the authors [31] in (2021) offered an intelligent solution for managing fish farms by leveraging IoT and machine learning. It utilized components such as Arduino Mega, ESP32, programming in the C language, WIFI, and the MQTT protocol to collect real-time data from fish farms and transmit it to farmers' smartphones. For the classification of fish diseases, a Convolutional Neural Network was employed. This proposal encompassed water quality monitoring, issue detection, alerts, remote control of pumps, fish disease detection, and a digital community for fish farmers to enhance their activities, increase their income, and contribute to data integration. However, the system presented some limitations, including its dependence on WIFI connectivity and challenges in terms of accuracy in fish disease classification.

The (IoT) has been a cornerstone in the domain of intelligent agricultural technology, linking all elements of smart systems, not just within agriculture but also extending to various applications. The research undertaken by the authors [32] in 2021, investigated the integration of it with unmanned aerial vehicle (UAV) systems and AI-controlled robots, while recognizing the challenges associated with their implementation in developing countries. Lately, the effectiveness of smart agriculture has become intricately linked to the rapidity of data transfer. Consequently, this research underscored the significance of the advent of 5G technology in the realm of smart agriculture, providing adaptable and efficient solutions due to its substantially enhanced speed compared to fourth-generation networks.

Soilless plant cultivation is a prevalent practice, and aquaponics, combining hydroponics and aquaculture (fish farming), offers numerous advantages. It eliminates soil-related diseases, reduces insect infections and pests, and allows for decreased pesticide usage within the monitoring system, minimizing toxicity. In the 2021 study conducted by researchers [33], hydroponic and aquaponic systems were thoroughly examined, emphasizing the integration of IoT devices for environmental monitoring and regulation. The objective was to establish an intelligent aquaponic architecture using IoT technologies, providing patterns and details for its prospective implementation. The article presents a comprehensive comparative analysis of both architectures, with the hydroponic system seamlessly integrated into the aquaponic system. This integration forms a holistic framework facilitating fish, plant, and organic food production. Furthermore, the study explores the implementation of a prediction system based on machine learning algorithms for analyzing data from IoT devices. By leveraging (AI) and (DL), the comparison of growth conditions and environmental data enhances the overall environment, reduces human intervention, and enables real-time

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data exchange. The article discusses various IoT solutions for controlling and monitoring the agricultural environment, incorporating sensors, actuators, and IoT devices. These solutions vary in terms of materials used, fostering greater diversity in agriculture. However, this diversity raises concerns related to energy consumption, data security, cost, interoperability, and food quality.

The rapid depletion of oceanic resources over the past decade has underscored the vital importance of aquaculture for food security. Water quality is a crucial parameter for the success of aquaculture, making real-time water quality monitoring essential. In this article, the authors [34] in 2022 presented an economical and easy-to-install artificial intelligence (AI) buoy system. This device, incorporating the RS-485 standard to ensure sensor measurement stability, provides aquaculturists with the flexibility to change sensors according to their needs. The use of LoRa wireless communication allows the buoy to transmit water quality data with low energy consumption, even over long distances to a coastal server. Data stored on the server is used to train machine learning algorithms that intelligently predict water quality, particularly in terms of temperature and speed. Furthermore, data from the flow sensor contributes to estimating water speed, enabling the creation of an affordable flow meter. This buoy system collects information on water temperature and speed, thus facilitating the integration of predictive capabilities. The results of these predictions have been used to develop another artificial intelligence function that estimates the feeding needs of sea cages based on water speed. This enhanced knowledge of feeding quantities can be valuable for aquaculture staff by guiding them toward appropriate bait quantities, reducing bait wastage, lowering feeding costs, and minimizing oceanic pollution.

The evaluation of fish weight and mass in aquaculture is crucial for determining the optimal time for harvest. Typically, this assessment involves the manual handling of fish, which can stress them for extended periods. To address this issue, the authors of this article [35] in 2022 presented a non-invasive method. This method starts by identifying the fish and then measures their length and weight, thereby reducing the stress associated with manual handling. This approach is faster than manual methods and offers greater flexibility in the face of environmental changes or variations in species. The increasing use of (AI) is expected to enhance control in many production systems. The primary objective was to obtain precise measurements of fish weight and length without manual manipulation, thus reducing stress and saving time. Through tools like an infrared light with a filter, fish were automatically detected, enabling the calculation of weight, length, and even an estimation of future weight. Ultimately, the system depends on a mathematical model to predict the forthcoming weight and length of the fish.

The (IoT) emerged as a crucial technology, offering effective and reliable solutions across diverse sectors, including smart agriculture and climate change mitigation. This development entailed the interconnection of billions of smart devices capable of communication, streamlining automated management and monitoring in smart agriculture and environmental domains. Through the integration of IoT, AI, and blockchain, smart agriculture underwent a transformation into an Internet of Smart Agriculture. The authors of this article from 2022 [36], synthesized cutting-edge technologies, including the (IoT), (AI), (ML), and blockchain, with potential applications in the domain of Climate-Smart Agriculture (CSA). This approach aimed to enhance agriculture by automating agricultural technologies to ensure sustainability and efficiency while preserving the environment. The article also delved into CSA concepts and applications, proposing a perspective that combines (IoT), (ML), and blockchain to fortify CSA. As a result, it provided valuable guidance to farmers and experts seeking to effectively navigate these smart agricultural technologies, relevant to diverse areas like water management and pest control, addressing challenges related to sustainability and climate change.

Aquaponics, an innovative and environmentally friendly agricultural technology, merges aquaculture (fish farming) with hydroponics to cultivate vegetables in a synergistic manner. Its appropriate use promotes the production of healthy organic food while reducing water consumption and the use of chemical fertilizers. This article by the authors [37] in 2022 conducted an in-depth analysis of research devoted to automated and operational aquaponic systems. It explores the various parameters related to aquaponics, highlighting scenarios of intelligent automation and the use of the (IoT), illustrated by examples and research findings. Additionally, the article identifies potential gaps in the literature and possible future contributions to automated aquaponics. This research suggests that aquaponic systems supported by intelligent control units have the potential to become more cost-effective, smarter, more accurate, more efficient, and economically viable.

The aim of this research is to showcase the application of the (IoT) in enhancing the breeding of

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black soldier flies (BSF) and mitigating food waste. This 2022 study by the authors [38] concentrates on establishing an automated smart agriculture system for BSF breeding, utilizing IoT for remote monitoring of the BSF farm, and facilitating real-time tracking of growth with the necessary adjustments. Moreover, it underscores the potential of smart agriculture, suggesting that if implemented extensively in BSF breeding, it can prove cost-effective and efficient in producing BSF larvae for diverse applications, such as organic waste management and the generation of valuable compounds. The study also brings to light that BSF larvae are abundant in bioactive compounds, presenting numerous applications in various fields. The utilization of IoT simplifies these processes through advanced technology.

Deep learning is gaining traction across various industries, including aquaculture. Progressing toward smart aquaculture necessitates the accurate identification of fish biodiversity and real-time monitoring of their behavior to optimize feeding management. The primary goal of this study conducted by the authors [39], in 2022 is to develop an efficient (CNN) for categorizing fish behavior into two distinct classes: normal and starvation, within the context of smart aquaculture. The study evaluates various configurations of connected layers, and the incorporation of three such layers, in conjunction with max-pooling, enhances detection accuracy by 10%. The outcomes indicate that the proposed model effectively addresses the issue of low generalization capacity observed in shallow neural networks, achieving an impressive 98% accuracy in classifying fish images. This system represents an innovative stride towards establishing an automated fish behavior identification system in modern aquaculture.

The emergence of the (IoT), particularly the rapid advancements in (UAVs) and (WSNs), holds the promise of precise and cost-effective applications in agriculture, including aerial crop monitoring and intelligent spraying operations. In their 2022 article [40], the authors conducted research on the potential use of UAVs. In precision agriculture (PA), exploring recent advancements in integrating UAV detection systems and AI algorithms into PA applications. The article also discusses the challenges and prospects for the future development of these technologies. Its objective is to stimulate prompt research, deployment, and utilization of AI-powered UAV detection systems in PA applications, addressing future challenges in agriculture and nutrition.

The 2022 article by [41] introduces a blockchain-enabled optimization strategy for greenhouse systems, comprising three stages: prediction, optimization, and control, with the goal of achieving an optimal greenhouse environment. In the initial stage, a Kalman filtering algorithm predicts sensor data within the greenhouse. Following that, optimal parameters for the indoor environment are calculated, and these optimized parameters are then utilized by the control module to activate and regulate actuators, ensuring the desired conditions within the greenhouse. To assess the performance of this greenhouse system, the authors created an emulation tool, comparing it to a baseline approach in terms of production rate and energy consumption. The results indicate a 19% improvement in energy consumption compared to the forecast-based approach and a 41% enhancement compared to the reference scheme. Additionally, a proof-of-concept based on Hyperledger Fabric was implemented on the proposed greenhouse platform. Through experiments evaluating throughput, latency, and resource utilization using Hyperledger Caliper, the results confirm the efficiency of the proposed optimal greenhouse system.

In their 2022 the authors [42], introduced AKMS-AgriIoT, a blockchain-based security solution tailored for agricultural (IoT) settings, specifically within the domain of Smart Precision Agriculture. Functioning as an authentication and key management scheme, AKMS-AgriIoT employs a private blockchain to secure communications among smart devices, drones, and ground station servers (ESGs). Cloud servers utilize blocks generated from encrypted transactions and their corresponding signatures by the ESG to verify and append blocks to the core of the private blockchain. Compared to alternative schemes, AKMS-AgriIoT delivers superior security features and functionality while maintaining comparable communication costs and reduced computing expenses. A thorough security analysis demonstrated AKMS-AgriIoT's resilience against common potential attacks in an IoT environment. Moreover, a comparative study revealed that AKMS-AgriIoT achieves a more favorable balance between security, functionality, communication costs, and computing costs compared to alternative systems. This blockchain-based solution significantly contributes to fortifying the security of IoT environments in agriculture, fostering safer and more reliable precision agriculture practices.

By crafting a prototype rooted in the amalgamation of the (IoT) and (AI), the authors [43] in 2022 have introduced an intelligent monitoring system tailored for aquaculture, specifically forecasting the growth of California Bass fish. This innovative system leverages IoT and AI to construct a predictive deep learning model for fish growth

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through the collection and analysis of pertinent data. The intelligent fish pond incorporates components such as an integrated Wi-Fi Arduino Mega2560, various actuators (heating, limiter, water pump, agitator, wind-blocking device, smart feeding device), and IPCCAM for real-time monitoring. The deep learning model seamlessly integrates into a self-sustaining feeding system, thereby minimizing food wastage. The application of AIOT in aquaculture empowers fish farmers to remotely oversee pond equipment, enhancing industry efficiency and facilitating the entry of new stakeholders. This paradigm shift towards a high-quality aquaculture sector holds the promise of significant financial gains, revolutionizing the landscape of fish farming. Intelligent management systems enable farmers to amass real-time data, optimize fishing performance, and invigorate metabolic processes. The expeditious and meaningful data collection on cage fish feeding is underscored by an impressive R2 of 0.94 and a mean squared error of 0.0015 during validation, attesting to the efficacy of the optimal model in accurately predicting fish growth over a span of 52 weeks.

In their research published in 2023, [44] explored recent advancements in the field of cattle farming using the (IoT) and Digital Twin Technology (DTLF). Their study focused on the design, platform, and topology of cattle farming systems that allow for data collection on animal health and support IoT infrastructure. They used various technologies such as GPS, RFID devices, and computer vision to achieve automated tracking of animals. Their research also encompassed aspects related to cattle feeding and well-being. To do this, they developed a tracking service prototype and tested various livestock-specific sensors and IoT protocols. The proposed system enables a website to update real-time information such as the animals' body temperature and their location. Sensors, whether installed in the environment or worn by the animals, collect real-time data, allowing for the tracking of animal location and monitoring their temperature. This information can be wirelessly transmitted to the website, which can make immediate adjustments. The primary goal of this study is to integrate Digital Twin Technology with IoT in the cattle farming sector, enabling the monitoring of animal well-being and improving farming precision. Evaluated parameters include efficiency, heart rate, disease detection, animal humidity, and temperature.

In 2023, the authors [45] proposed a solution based on LoRa (Long Range) and the Internet of Things (IoT) for irrigation management. This solution aims to create an intelligent irrigation planning and monitoring system for tomato and eggplant crops. It uses soil moisture sensors to collect data on the water needs of the crops. Compared to traditional irrigation, where water needs were 7541 ml for banana trees and 8755 ml for rice, the IoT-based irrigation system reduced water consumption to 5010.745 ml and 4421.09 ml respectively in one month. This reduction in water consumption amounts to a 46% reduction compared to traditional irrigation while maintaining plant health. The developed system also allows for remote monitoring of soil conditions and efficient data storage through IoT. Soil and meteorological data from weather stations are sent to IoT cloud services for monitoring and storage with an optimal computing cost. In summary, this LoRa-IoT-based solution improves irrigation management by reducing water consumption while preserving plant health. It also offers remote monitoring of soil parameters and weather data, contributing to more efficient agricultural management.

Aquaculture sought to improve its efficiency through data-driven management, with biofloc (BFT) emerging as an environmentally sustainable method to mitigate its ecological impact. However, for the aquaculture industry's sustainability and management enhancement, the integration of BFT with other technologies was imperative. In 2023, researchers [46] explored the potential integration of biofloc technology (BFT) in upcoming advances in aquaculture, viewing BFT as an innovative solution to address pollution, high costs, and low productivity issues associated with traditional aquaculture. Ongoing research focused on applying BFT to the farming of aquatic species, which involved maintaining an appropriate carbon-nitrogen ratio by introducing a carbon source, fostering the growth of microorganisms, and preserving water quality through nitrification. To optimize BFT, various parameters such as suspended solids, water turbidity, temperature, dissolved oxygen, pH, salinity, stocking density, and light needed to be considered. The incorporation of Fourth Industrial Revolution technologies, including Information and Communication Technologies and the (IoT), presented an opportunity to mitigate risks and automate tasks in aquaculture. By integrating ICT, IoT, and BFT technology, it became conceivable to monitor crucial parameters for BFT farming in real-time using sensors. This approach held the promise of enhancing efficiency by supporting the growth and health of cultivated aquatic organisms.

Advances in information and communication technology (ICT) in the aquaculture sector are clearly evident, encompassing the transition from wireless sensor networks and the (IoT) to the development of predictive models using (AI). These technologies are being implemented to monitor and optimize fish farming by controlling critical parameters, aiming to enhance long-term productivity. The authors of this article [47], in 2023, conducted a comprehensive analysis of a systematic literature review to identify key factors that promote improved sustainable productivity in freshwater and inland aquaculture. They also aimed to identify (ICT), particularly the (IoT) and (AI), that are most commonly used globally to monitor and manage these factors in five key areas: water quality, fish feeding, water recirculation, fish transportation, traceability, and fish welfare. The evolution of ICT tools in aquaculture ranges from basic sensors to the implementation of predictive models based on deep learning. However, it is worth noting that there are few studies evaluating the impact of these tools on the productivity of freshwater aquaculture under real conditions. Furthermore, it is evident that the number of projects focusing on the application of artificial intelligence in aquaculture is steadily increasing. Nonetheless, ensuring the credibility of the results of these projects requires enhanced collaboration among different research groups worldwide. This collaboration will promote the reproducibility and comparability of results, which, in turn, will drive progress in this field of applying ICT tools.

Aquaculture, which involves the cultivation of various aquatic species in controlled environments, requires real-time monitoring of environmental conditions to ensure its success. The (IoT) presents a significant opportunity for this real-time monitoring. In their 2023 article [48], the researchers have developed an embedded IoT system specifically designed to monitor and control water quality in ponds efficiently, with the aim of preserving fish life. Water quality parameters are continuously measured, and the data is stored in the ThingSpeak cloud. After analyzing the results, it was concluded that ponds 1, 3, and 4 offer ideal conditions for fish farming due to their optimal levels of pH, temperature, turbidity, and conductivity. In contrast, ponds 2 and 5 are not suitable for this activity. Thus, ponds 1, 3, and 4 are recommended for fish farming, while ponds 2 and 5 can be utilized with the support of ML algorithms. Ten of these algorithms were employed to analyze the data collected by the sensors, and among them, Random Forest stood out with an accuracy of 94.42%, a kappa coefficient of 93.5%, and an average true positive rate of 94.4%. Furthermore, an analysis was conducted on Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), and dissolved oxygen levels for a specific scenario.

Digital twins enable precise simulation and analysis of physical systems, efficiently utilize data from multiple sources, and facilitate remote monitoring and control of physical systems. In this article, the researchers [49], in 2023, focused on creating a comprehensive Internet of (AIoT) environment using big data analysis and smart cloud, with a digital twin. This system offers various services such as feeding, fish assessment, monitoring, and health management. It aims to assist aquafarm managers in making informed decisions. The (ML) and (DL) structures of AI analyze big data to anticipate and optimize procedures, thereby facilitating information-based decision-making. AIoT provides real-time access to aquafarm data, enabling remote supervision by owners, employees, and other stakeholders. While the concept of a digital twin is new in aquaculture, it provides remote farm monitoring, benefiting farmers. This innovative advancement combines digital twin services for smart aquaculture with versatile artificial intelligence features in the sea or offshore.

Aquaculture plays a key role in Taiwan's economy, and precise monitoring of the level of dissolved oxygen (COD) in fish farming water is crucial for ensuring efficient production. To address this challenge, researchers in this study [50] in 2023 developed an IoT system specialized in monitoring water quality by collecting essential data and using artificial intelligence to predict water quality. Given the complex interaction of factors affecting water quality in aquaculture and its relationship with the previous state, this research employed (RNN) with sequential features. Among these RNNs, the 7-layer GRU model was identified as the most suitable for the studied application, displaying impressive performance with an average absolute error of 3.7134%, a mean square error of 0.0638, and an R value of 0.9984. This study, conducted in partnership with the Taiwan Institute of Industrial Technology and a local fishing company, confirmed the efficiency and practicality of the monitoring system to improve the survival of farmed fish by maintaining dissolved oxygen levels above required standards. The developed method provides an automated, secure, energy-efficient, and reliable solution for monitoring fish farming ponds. The results of the experiment validated the effectiveness and usefulness of this system designed by the research institute.

3.2 IoT-HealthCare

IoT plays a crucial role in data collection and monitoring, while AI takes responsibility for analyzing the ever-growing volumes of data and making decisions based on the information extracted from this data. In this article, the authors [51], in 2018, also explored the main categories of applications, including wearable devices and connectivity, disease detection and management, patient care, and sensor networks. These applications offer many potential benefits for patients, healthcare providers, physicians, and healthcare facilities. However, the success of healthcare applications using technologies such as IoT and AI depends on the acceptance of these technologies by healthcare professionals and patients, the development of stronger and more uniform data security and privacy regulations, as well as the improvement of system efficiency and safety.

Researchers, including [52] in 2018, presented a dedicated security scheme for IoT in the healthcare domain. Their approach proved to outperform other security schemes, providing a comprehensive range of features. It is based on generating cryptographic keys based on ECG for medical sensors, secure authentication and authorization of medical IoT devices using DTLS (Datagram Transport Layer Security), as well as robust and secure end-to-end communication through DTLS-based session resumption. Tests confirmed that their ECG-based key generation method is faster and more energy-efficient than similar approaches. Their scheme reduces communication overhead by 26% and decreases communication latency by 16% compared to existing schemes. In summary, this solution ensures secure IoT communications for healthcare systems at a lower cost. Their future work will focus on analyzing trade-offs between security, latency, and energy consumption.

The NB-IoT (Narrowband Internet of Things) technology is a solution for long-range, low data rate communications, ideal for sensors requiring low processing complexity and long battery life. In the article by [53] in 2018, the focus is on evaluating the performance of NB-IoT in the context of medical monitoring, examining both SND (Single Number Density) and MND (Multiple Number Density). The study results reveal that the MND approach improves both throughput and patient capacity per cell. However, this improvement comes with a slight increase in latency due to reduced overhead related to control information transmission. In summary, it is crucial to simultaneously optimize throughput, latency, and device density to tailor the solution to different usage scenarios.

IoT in healthcare presents challenges related to latency, data management, user expectations, and application diversity. Research is turning to Cloud Computing to develop IoT solutions. However, this framework has limitations in terms of distance between hops relative to the data source, geographically centralized architecture, and economic aspects. To overcome these limitations, solutions using Fog Computing are emerging to bring computing resources closer to data sources. This approach is encouraged by the increasing availability of cost-effective decentralized computing and commercial developments in this field. However, ensuring interoperability and integration between the Cloud and the Fog involves complex coordination of applications and services, as well as the establishment of intelligent service orchestrations to optimize the use of distributed resources while maintaining stability, service quality, and security. In this work, the authors [54], 2018, presented a literature analysis that provided the motivation to extend the structure of the Cloud-based IoT-Healthcare solution. This proposal consists of a Fog-based IoT-Healthcare solution that is interoperable with the existing structure but benefits from functional enhancements. They studied the integration of these two interoperable structures through a reference architecture and conducted simulations in iFogsim (an open-source simulation framework) to evaluate their performance. The results show that the Fog-based solution improves service distribution, reduces instance costs, decreases energy consumption, and reduces network latency.

The integration of the CloudIoT model in the healthcare domain offers numerous opportunities for medical technologies, enhancing healthcare services, and fostering innovation. An article authored by [55] in 2019 conducted an in-depth analysis of the integration of Cloud Computing and the (IoT) in the healthcare sector. This analysis encompasses areas such as smart hospitals, medication management, and remote medical services. The article also provides a brief introduction to Cloud Computing and the (IoT), illustrated with examples of applications in the medical field. A novel concept, termed CloudIoT-Health, combines Cloud Computing and the (IoT) in the healthcare domain. The terms and issues related to this integration are presented to offer a clear perspective on the subject. The objective of this article is to assess the current state of component integration in CloudIoT-Health systems while identifying areas in need of improvement. It also examines existing research on the integration of Cloud Computing and the (IoT) in healthcare systems, highlighting the challenges to be addressed and suggesting future research directions, accompanied by a comprehensive bibliography.

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In the field of healthcare, recent studies have led to the development of a non-invasive wearable device using Bluetooth Low Energy (BLE) technology to monitor vital signs. The authors of this study [56], in 2019, combined this device with a smart terminal to create an (IoT) based healthcare solution. While many previous studies used electrodes to perform electrocardiography (ECG) and photoplethysmography (PPG) measurements based on the reflection of LED light, this new approach relies on a PVDF film sensor worn on the wrist. This sensor enables the detection of cardiac vibrations and the calculation of heart rate from signals emitted by the radial artery. This innovation reduces energy consumption while improving accuracy through signal-to-noise ratio (SNR) optimization via a filtering circuit and peak detection algorithm. The collected data is transmitted to the cloud, providing users with real-time monitoring of their vital parameters while allowing medical facilities to access it in case of emergencies.

An innovative blockchain model dedicated to the (IoT) has been specially designed for Remote Patient Monitoring (RPM). It offers patients the ability to receive healthcare services while in their own homes, using wearable IoT devices. These devices collect a range of data, including blood sugar levels, blood pressure, and respiratory habits, which they then transmit to healthcare professionals. The primary goal of the authors of the article [57] in 2019 was to design a lightweight version of the blockchain while maintaining levels of privacy and security. To achieve this goal, they eliminated the concept of proof of work that was present in the initial model. Thus, the privacy and security of the proposed model are based on its decentralized nature. This model consists of five key elements: the blockchain network, cloud storage, healthcare providers, smart contracts, and patients equipped with IoT devices. In order to improve the overall system efficiency without compromising security, the authors implemented an overlay network that subdivides the blockchain into clusters of nodes. This approach aims to reduce overall costs and latency while maintaining system integrity.

The advent of (IoT) technologies in the healthcare sector has brought about significant changes to the industry. However, this interconnectivity has also opened the door to potential vulnerabilities and attacks, allowing attackers to target medical devices. Despite the high risks to the healthcare environment and security, IoT solutions in healthcare offer undeniable benefits. In this study, the authors [58], in 2019, proposed an IoT security risk management model aimed at ensuring secure practices in the healthcare domain. They reviewed IoT-related risks from previous studies and selected a Malaysian government hospital as a case study. The results enabled the formulation of a model encompassing IoT security risk management, Hospital Performance Indicator for Accountability (HPIA), and implementation phases. This model was successfully developed and remains to be validated in the next stage, involving participants from the case study.

In the study conducted by [59] in 2020, the authors highlight the importance of the BPMN (Business Process Model and Notation) standard as a standard for modeling operational processes. They emphasize that healthcare processes are increasingly integrating non-human participants, such as physical (IoT) devices, including biomedical sensors and patient electronic tags. The critical nature of these healthcare processes related to IoT requires consideration of service quality factors such as reliability, availability, and cost. The article's objective is to focus on the reliability of healthcare processes in BPMN associated with IoT. The authors propose the use of the Stochastic Workflow Reduction (SWR) method to calculate the reliability of these processes. Furthermore, they recommend an extension of the BPMN language to incorporate reliability information into process models. This approach allows modelers to analyze different alternatives during process design, and reliability information can be used during execution to select participants, perform services, or monitor process progress. This proposal is particularly relevant for a use case related to an independent living support system. In summary, the article presents a comprehensive solution for calculating the reliability of BPMN healthcare processes integrating IoT. This approach is based on an extension of the BPMN language that adds reliability information to various process elements, such as activities, events, gateways, subprocesses, loops, and multi-instance activities.

A portable physiological monitoring framework ensures continuous monitoring of heart rate, body temperature, and other essential parameters. In an article written by [60] in 2020, a continuous monitoring tool is presented to filter the patient's condition and store their information on a server using Wi-Fi connectivity. They introduced an Internet of Things (IoT)-based health telemonitoring system that allows authorized medical personnel to access this data through any IoT platform. Based on this data, remote doctors can make medical diagnoses. This system relies on the use of sensors to monitor body temperature, pulse, ambient humidity, and temperature, displaying this data on an LCD screen. The collected information is then wirelessly transmitted to a medical server and subsequently to a personal smartphone with an authorized IoT platform. The doctor can then make a medical diagnosis based on the obtained values.

This study focuses on the application of IoT in the medical field, specifically in the healthcare sector. It also explores future trends, including Bio-IoT and Nano-IoT. An essential component of vital signs monitoring in an IoT system is the Wireless Body Area Network (WBAN), which uses devices implanted on or inside the patient's body to enable wireless communication. In 2020, researchers from [61] developed a biomedical application based on a WBAN, which they tested at Ege University Hospital. This application collects data on the patient's heart rate, plethysmography, and oxygen levels, which are then wirelessly transmitted to a central database using IoT technology. The system's performance evaluation covers its reliability, data accuracy, network stability, and range. The prototype consists of modules interconnected with pulse oximeter sensors, programmed in the C language to create a wireless network. Cardiac, plethysmographic, and oxygen data are wirelessly transferred to a central database, where personal files are created for each patient. If necessary, customized thresholds can be set for each patient, triggering visual alerts to a central station or generating appropriate notifications. Tests confirm the system's reliability, feasibility, and self-configuration capability. In comparison to a wired connection, data accuracy is satisfactory, and the system exhibits minimal interference with other systems operating at 2.4 GHz, such as Bluetooth and Wi-Fi, which does not affect its proper functioning.

The (IoT) enables the connection of a multitude of devices via the internet to collect data, particularly in the field of healthcare. Patients use wearable or implantable medical sensors to continuously monitor their medical parameters, but these sensors are powered by batteries with limited lifespans. To extend the network's durability, it is imperative to adopt efficient routing protocols. In this article, researchers [62] in 2020 introduced PEERP, an Energy-Efficient Routing Protocol based on Priorities for Reliable Health Data Transmission via IoT. They classified health data into two priority categories: Emergency Situations, which require fast delivery, and Vital Health Data, crucial for continuous patient monitoring. Critical data is transmitted using direct communication, while health data is routed via multi-hop communication. Simulation results highlight the improvement in sensor energy efficiency through this routing protocol, which extends the network's lifespan and ensures a reliable delivery rate.

Fog Computing brings data processing closer to healthcare centers. The combination of IoT and Fog Computing is being developed in healthcare to accelerate services and infrastructure, potentially saving lives. In this article, the authors of [63] in 2020 proposed a computing platform based on the concept of Fog Computing that reduces transmission latency and communication with remote servers, rapidly improving medical services. Latency is crucial in healthcare projects and sensitive services. Reducing data transmission costs to the cloud is a significant research goal.

In 2021, a study conducted by [64] presented an innovative diagnostic model for a smart healthcare system that combines (AI) and (ML). The main goal of this research was to develop a diagnostic model for heart diseases and diabetes using AI convergence techniques. This model encompasses various steps, including data acquisition, preprocessing, classification, and parameter tuning. Within this model, AI techniques and IoT devices facilitate disease diagnosis. To achieve this, the CSO-CLSTM (Cascaded Long Short-Term Memory) model based on the Crow algorithm is used. The CSO is used to adjust the weight and bias parameters of the CLSTM model, which contributes to improving the classification of medical data. Additionally, the iForest algorithm is implemented to eliminate outliers. The results of the CSO model significantly improved the performance of the CLSTM model during testing with health data. Ultimately, this CSO-LSTM model achieved a maximum accuracy of 96.16% in diagnosing heart diseases and diabetes.

COVID-19, a global infectious disease, spreads easily through contact with infected individuals. In the context of global research, the (IoT) is being leveraged to develop reliable diagnostic, assessment, and treatment procedures to prevent and mitigate the impact of COVID-19 in sustainable smart cities. The article by the authors [65] in 2021 sheds light on the crucial role of IoT in reducing contagion within these sustainable smart cities. This study focuses on IoT applications in healthcare, with an emphasis on network security, reliability, authentication, and data preservation. It also identifies current challenges and outlines directions for future research. A comprehensive analysis of the literature on COVID-19 from 2019 to 2021, with a focus on IoT in healthcare, is at the core of this study. It highlights current limitations of IoT applications in healthcare,

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particularly in terms of network and communication security, while offering recommendations for addressing these challenges. Furthermore, they will explore future research directions in the context of the increasing use of IoT in healthcare to deal with COVID-19, with the aim of achieving productive outcomes and reducing infrastructure-related costs.

Emerging technologies such as the (IoT) and (AI) are crucial in the development of Smart Cities. They improve healthcare while reducing costs. The integration of IoT and AI is key in telemedical monitoring. Mastery of IoT, AI, and ML is critical in systems that collect vast amounts of data. Through machine learning, these systems generate analyses for clinical decisions and healthcare. They provide personalized treatments, lifestyle recommendations, and care plans by analyzing data. In 2022, [66] studied the use of this technology to monitor health parameters in urban environments. Their research emphasizes applicability and presents innovative concepts. Areas covered in this implementation include active aging, population monitoring, healthy lifestyles, socialization, healthcare service organization, and emergency response. Additionally, the paper proposes a secure and cost-effective method to develop a real-time health monitoring system using IoT and machine learning technology.

Rural areas in many countries suffer from a lack of access to medical services, making remote patient monitoring essential for various conditions, including COVID-19, hypertension, and diabetes. To address this gap, a team of researchers led by [67] developed a health monitoring system based on the (IoT) in 2022. This system relies on the use of sensors to collect data such as blood oxygen levels (SpO2), heart rate, and the patient's body temperature. This information is then transmitted and displayed on a dedicated web platform. The major advantage of this system is its compactness, speed, and cost-effectiveness, making it more accessible and easier to implement in the medical field. In case of emergencies, the reports generated by the system are directly sent to healthcare professionals, enabling them to take immediate actions based on this data.

EPPADA is an efficient authentication scheme that leverages the (IoT) and environmentally friendly computing technologies to meet healthcare requirements while preserving data privacy and aggregation using homomorphic encryption concepts. This approach reduces the data traffic of the EPPADA system, effectively minimizing energy consumption and extending the network's lifespan. Furthermore, EPPADA ensures data privacy and integrity through homomorphic encryption. In an article authored by [68] in 2022, an experimental system was developed using the E-health sensor shield V2.0 platform. This system underwent testing and evaluation based on four performance indicators. A thorough security analysis showed that our proposed plan is characterized by low computational overhead, reduced communication costs, and overhead control.

The use of digital technologies is crucial in anticipating, preventing, and controlling emerging infectious diseases. Bangladesh, a country characterized by high population density and a fragile economic situation, faces the challenges of COVID-19 and dengue. The absence of a digital healthcare system, inadequate preparedness, and lack of public awareness are major obstacles that threaten the population and contribute to the worsening of epidemics. In this article from 2022, the authors [69] presented a proposal to establish a digital healthcare and surveillance system based on the (IoT) and (AI). This system aims to enable the rapid detection of COVID-19 and dengue cases while improving control strategies at the national level.

Blockchain is a highly praised technology with potential benefits in both IoT and healthcare, as stated by [70] in 2022. Blockchain is essential for enhancing data security in the healthcare and IoT sectors, offering specific strategies to ensure this security. Publications explore the integration of blockchain with IoT, including medical IoT. Three distinct mechanisms have been identified for integrating blockchain into IoT. Various approaches are considered, ranging from full integration into data exchanges between devices to more targeted use focused on metadata storage. Blockchain is widely used in the smart city sector to facilitate real-time data sharing, electricity trading, and other applications. It is also utilized in the healthcare sector to manage the drug supply chain and give patients control over their data, thus helping to combat counterfeiting.

Individual health is of paramount importance, but technological limitations in the healthcare field often hinder the quality of treatments. The (IoT) is emerging as a solution to these problems by offering applications in disease detection, treatment, and monitoring. Wearable devices, which are an integral part of IoT, play a key role in helping patients receive proper care. This article authored by [71] in 2022, highlights the importance and impact of 5G technology in the context of IoMT (Internet of Medical Things), IoT, and IoT-based wearable devices. It also examines the persistent vulnerabilities

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in some wearable products and the challenges that researchers will face in the future. This review has the potential to guide the development of IoT-based wearable devices aimed at improving healthcare delivery. It is the first synthesis addressing the impact of 5G technology on IoT, as well as the opportunities, applications, and challenges of IoT-based wearable devices. The authors anticipate a true revolution in IoT and wearable devices through 5G. This article focuses on IoT, IoT-based wearable devices, and 5G in the healthcare sector. It also explores how wearable devices can be used to detect health issues, treat patients, and diagnose diseases. The article underscores the importance of IoT and its wearable devices while identifying the looming research challenges.

Artificial intelligence tools have been used to design an innovative system that consists of two distinct components: health monitoring based on the (IoT) and medical diagnosis based on fuzzy logic. This approach, presented by [72] in 2023, aims to address critical patient needs, including those with COVID-19 and those isolated in remote areas. The system was designed to allow doctors to interact with patients in case of emergencies using sensors, cloud storage, and a communication system via SMS and emails. It offers particular utility for isolated patients and remote areas. The intelligent algorithm integrated into the system preprocesses ECG signals by passing them through six digital filters. It then calculates and evaluates signal characteristics to make an autonomous diagnosis. The algorithm's efficiency is attested to by its high accuracy, which results from its training with ECG data from the MIT-BIH database. Real-time tests have shown that the fuzzy algorithm achieves an accuracy of nearly 100%. This intelligent system is highly versatile and can be applied in various contexts, but it is particularly valuable for COVID-19 patients who are isolated and dealing with critical cardiac arrhythmia issues that require intensive care.

Machine learning-based authentication models have some limitations, including their sensitivity to imbalanced datasets and the complexity of integrating new users into the system. To address these issues, the authors, namely [73], proposed an innovative approach in 2023. They suggest using electrocardiographic (ECG) signals, which are readily available within digital healthcare systems, for authentication. This method relies on using a Siamese Network Ensemble (SNE) capable of handling slight variations in ECG signals. The addition of a preprocessing step to extract features in this model resulted in improved results. Tests were conducted using the reference datasets ECG-ID and PTB, leading to accuracy rates of 93.6% and 96.8%, with error rates of 1.76% and 1.69%, respectively. This model is particularly suited for the fields of smart healthcare and telehealth due to its robustness, simplicity, and data accessibility. Thus, the system can account for individual variations in ECG signals, whether they result from health issues, physical activity, or other factors. This approach enhances the accuracy and reliability of the authentication system. Moreover, the use of a Siamese Network Ensemble (SNE) helps address common issues related to imbalanced datasets and the complexity of adding new users to machine learning-based authentication models.

Healthcare systems based on the (IoT) utilize data from IoT devices to automate decisions and offer recommendations for enhancing users' health. However, the utilization of unreliable data can result in inaccurate health decisions and inappropriate suggestions. In a 2023 article [74], proposed a trusted computing model for the Health Index Evaluation System (HIES). This HIES system depends on trustworthy data selected through this trust model to compute the health index of a specific user. The primary objective of this study is to establish a reliable system that improves circadian health decision-making by evaluating the reliability of data from health IoT devices. This trust model considers factors such as device and user identity, device health, user feedback, data consensus, and acceptance rate for selecting trusted data. The trusted computing model is crafted to identify malicious devices and incorrect data, as evidenced by simulation results. With this trust model, users can effectively and reliably monitor their circadian rhythm. Furthermore, a trust-based health recommendation system could be developed to assist users in making changes to their daily routine to enhance their health score.

In this 2023 article, [75] introduced HealthEdge, an intelligent health framework using machine learning to predict type 2 diabetes. HealthEdge integrates IoT, cloud, and edge processing. Experiments and comparative analysis were conducted on two diabetes datasets using commonly used machine learning algorithms, namely Random Forest (RF) and Logistic Regression (LR). The results show that RF predicts diabetes with an average accuracy about 6% higher than LR. This health framework addresses the need to anticipate type 2 diabetes using machine learning. It analyzes risk factors using sensors and predicts an individual's likelihood of developing diabetes. The machine learning model is trained in the cloud and used by edge servers to predict diabetes. The system's performance is evaluated using two commonly used ML algorithms, based on real diabetes data.

Advancements in healthcare are propelled by the use of emerging technologies to elevate the quality of life through medical services. These services gather real-time data using body sensors and IoT medical devices, which is then consolidated into a centralized model. However, IoT-based medical services encounter challenges like data security, privacy, interoperability, risks of a single point of failure, scalability, and data integrity. The integration of blockchain technology with IoT emerges as a potential solution to these issues, aiming to enhance the healthcare system. In a 2023 article, the authors [76] presented a study exploring the integration of blockchain and IoT in healthcare services. The approach commences with an introduction to blockchain, IoT, and the underlying motivation for BC-IoT. Subsequently, existing healthcare applications are scrutinized. This article also delves into the role of BC-IoT in various areas, including remote patient monitoring, medical record management, healthcare asset tracking, and tracking COVID-19 patient contacts, to deepen the understanding of these aspects. Ultimately, challenges and directions are addressed to improve patients' quality of life through these healthcare applications.

Portable Health Monitoring Systems (HMS), leveraging IoT technology for efficiency and reliability, play a pivotal role in telemedicine. Article [77] in 2023, introduces a portable health monitoring system in IoT, operated through an intuitive smartphone application. It continuously monitors physiological indicators and environmental conditions in real-time, automatically managing data. The solution stands out for its simplicity and independence, storing patient data on either a local or external server. This advancement integrates a smartphone application with a streamlined control interface, reducing complexity through the incorporation of components such as sensors, a GSM module, a microcontroller, Wi-Fi, and Bluetooth, resulting in the development of a compact and lightweight system.

3.3 IoT-Mobility (Transportation)

In the field of Intelligent Video Surveillance for the Public Transportation System (STS), Fog-FISVER is a specific framework that implements fog computing to cost-effectively enhance crime prevention. Through Fog-FISVER, both onboard and fog infrastructures support autonomous, real-time detection of criminal activities in public bus services. In a 2018 article, [78] presented a prototype of Fog-FISVER, which was developed and subjected to thorough evaluations in a real-world testing environment. The results demonstrate that Fog-FISVER offers outstanding system performance and device survivability compared to typical use cases of intelligent video surveillance-based STS. This approach enables the rapid and automated detection and prediction of criminal incidents while maintaining a low network cost.

Under the national Sii-Mobility project, a versatile platform was created to address the mobility and transportation demands within smart cities. This platform seamlessly incorporates sensors and actuators, including IoT/IoE, within a comprehensive framework encompassing Big Data, machine learning, and data analytics. This integration empowers the execution of intricate and varied scenarios. In 2018, [79] outlined a system in their article focused on altering traffic direction on a road segment in real-time, while ensuring compliance with all essential safety prerequisites. To substantiate this solution, an elaborate and intricate case study was conducted, scrutinizing multiple facets of the IoT platform. This case study exemplifies the platform's adaptability and dynamic configuration capabilities, accommodating security solutions across different tiers, whether at a local level, cloud-based, or employing a hybrid approach.

The (IoT) is revolutionizing our interaction with objects by connecting them to the Internet, especially in the realm of Intelligent Transportation Systems (ITS). These systems leverage various technologies such as wireless communication and GPS to provide more intelligent and responsive services to users, thereby enhancing their level of information and transport safety. However, the proliferation of connected objects within ITS generates a substantial amount of data. Typically, this data is transmitted to the cloud for analysis to uncover new insights. Nonetheless, this approach has its drawbacks, including issues related to latency and other challenges. A promising solution is to embrace fog computing (or edge computing), which enables data analysis and insights to be derived directly at the network's edge. This approach aims to reduce data processing delays compared to the cloud. Nevertheless, it's crucial to highlight that the fog computing model has limitations in terms of computing capacity. For Intelligent Transportation Systems that encompass a large number of connected objects, neither the cloud nor fog computing alone provides complete solutions to address all the challenges. That's why, in a 2018 article, [80] introduced a hybrid (IoT) model specifically designed for ITS. This hybrid model effectively overcomes the limitations encountered in various application scenarios.

In the realm of autonomous vehicles, including drones and electric cars, the article [81] in 2019 focused on a key challenge addressed by researchers: the establishment of a secure energy exchange system for charging and discharging vehicles in smart grids. Current approaches are often centralized and may not be well-suited for efficiently managing energy in a smart city. Additionally, the demand for real-time energy transactions is imperative for the Internet of Things. To overcome these challenges, the researchers introduced a system named BEST. BEST leverages blockchain technology to validate vehicle requests in a decentralized manner, thereby ensuring resilience against failures. Minor nodes are selected based on various factors, including energy requirements and dynamic pricing. Additionally, a software-defined network is employed to ensure low latency and real-time services, thus enhancing the overall security of the system.

In their 2019 article, [82] presented an architecture for an (IoT)-based smart transportation system that leverages big data analytics to perform real-time processing using Big Data techniques. This architecture aims to facilitate user-friendly communication in this context. The system is divided into three distinct phases, each responsible for organizing Big Data, real-time processing, and service management. By utilizing real-time processing of big data, this architecture provides a versatile solution for intelligent transportation planning. Various datasets were analyzed to validate the efficiency of this solution in real-time processing of intelligent transportation planning. The findings affirm the capability of the suggested system to proficiently manage the data.

The concept of the Internet of Vehicles (IoV) is gaining prominence within (ITS), combining the advantages of Connected Vehicles (VANET) and the (IoT). Internet of Vehicles (IoV) exhibits distinctive characteristics, including dynamic topological structures, an extensive network, reliable Internet connectivity, compatibility with personal devices, and significant processing capacity. In a 2019 article, the authors [83] conducted an in-depth examination of IoV and its applications in the field of intelligent transportation. Security in IoV raises major concerns due to the large amount of real-time critical data it generates. The article explores security requirements, challenges, and potential attacks related to IoV while reviewing existing security solutions. The analysis reveals that many of these solutions have a negative impact on network performance, especially concerning latency, which can be problematic for IoV and VANETs. To address this issue, the authors propose a lightweight authentication protocol based on Radio-Frequency Identification (RFID) technology to enhance IoV's security while improving network performance.

The public transportation system (PTS) in metropolitan areas is complex and challenging to manage. In 2019, the authors [84] discussed an innovative solution: An Internet of Things-based Intelligent Public Transportation System (IoT-IPTS) for metropolitan areas. IoT enables the connection of various components of the transportation system, such as vehicles, passengers, routes, roadside units, ensuring seamless connectivity across different network technologies, regardless of passenger or vehicle mobility. To provide public transportation tailored to metropolitan areas, the authors utilize information stored in the cloud. This information includes route conditions, traffic density, available routes, congestion, vehicle movements, and mobility. By using cloud-stored information and IoT, the system delivers efficient public transportation services for metropolitan areas. The IoT-IPTS employs both static and mobile agents, incorporating an Emerging Intelligence Technique (EIT) to collect, analyze, and share contextual information. The analyzed contextual information is used to formulate policies for providing the best public transportation services in metropolitan areas. The system uses a cloud-based Software-Defined Network and an EI network to manage public transportation services for passengers. This solution innovatively and effectively addresses the complex challenges of public transportation management in metropolitan areas.

In order to enhance Intelligent Transportation Systems (ITS), researchers [85] in 2020 proposed a distributed and secure fog computing network architecture that leverages blockchain technology. This innovative approach incorporates user and IoT device registration and authentication algorithms, enabling on-edge computing resources using smart contracts. They developed an aggregated signature scheme to generate a unique signature for multiple IoT devices. Evaluating this model through performance-based experimental analysis revealed a significant reduction in median latency at local

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nodes, reaching 81% compared to the baseline model. These results demonstrate the effectiveness of this solution, offering promising applications in the field of (ITS).

Mobile (IoT) has transformed our daily lives by equipping our vehicles with various IoT devices to make them smart. However, this convenience also exposes our privacy to risks of exploitation by attackers. In an article published in 2020, the authors [86] proposed an innovative query scheme aimed at ensuring the privacy of smart vehicles. This scheme allows vehicles to request services without revealing sensitive personal information such as their location or preferences. Furthermore, the researchers introduced a network coding mechanism to make this scheme adaptable to more complex top-K type queries involving the collaboration of multiple mobile IoT vehicles. They also addressed the issue of the provider's unnecessary data disclosure, given its high value. Performance and experience have shown that this scheme is not only valid but also more accurate and efficient than existing solutions in the context of mobile IoT. Thus, this innovative approach helps protect the privacy of smart vehicle users while providing them with a higher quality of service.

In the field of urban transportation systems, the (IoT) has become widely integrated into various transportation devices and entities. The concept of an Internet of Things-based Intelligent Transportation System (IoT-ITS) is gaining popularity among researchers and professionals. However, the complexity, diversity, and decentralization of the IoT network pose various challenges in terms of cyber-physical security. Moreover, the integration of 5G networks into public infrastructures connected to the transportation system via IoT raises geospatial security concerns. To address these issues, in their 2020 article, the authors [87] proposed a geospatial modeling approach to design a Geospatial Security System for Intelligent Transportation (GSS-IT). This proposal underwent modeling and simulations during an experimental study conducted in the city of Beijing, China. The results of these simulations are expected to provide a strategic guide for managing security in the context of intelligent urban transportation.

The integration of cloud, fog computing, and edge computing has a significant impact on modern transportation systems, especially in smart cities and the development of open data initiatives. Open data is crucial for providing real-time information to users of public and private transportation. In their 2021 article, [88] used machine learning and optimization methods to convert data into actionable knowledge, thus helping make informed mobility decisions for citizens. The article explores the need to develop agile algorithms to solve large-scale transportation problems in real-time. These algorithms rely on data collected through the (IoT) and open data, and they are based on the parallelization of biased-randomized optimization algorithms to improve the performance of a fast heuristic.

The rapid advancement of networking technologies, particularly the (IoV), has created an interconnected system between vehicles and infrastructure, evolving into a Smart Transportation System (STS) through AI and ML. However, the adoption of STS is hindered by operational issues, such as scalability and data privacy. To tackle these obstacles, the 2021 article [89] discusses the use of Federated Learning, a ML and AI technique for training a machine learning model. A case study demonstrates how Federated Learning can enhance the system's resilience by leveraging collective intelligence while reducing recovery times. Federated Learning is considered a crucial catalyst for STS, especially in 5G and beyond networks, offering numerous potential advantages.

In their 2022 article, the authors [90] presented a novel facial mask detection system based on the (IoT) for public transportation, with a specific focus on buses. This system employs facial recognition to collect real-time data, using advanced techniques such as (DL), (ML), and image processing to achieve its primary goal: real-time detection of facial mask wearing in a video stream. The researchers evaluated the model using recent datasets as well as publicly available datasets. The results demonstrated that the CNN classifier transformation outperformed the DNN classifier, being highly effective in identifying individuals wearing masks, with an error rate as low as 1.1%. This enhanced model delivers superior performance and excels in rapidly and efficiently detecting faces and masks while addressing the resource constraints inherent to the Internet of Things.

In their study, the article authored by the researchers [91] in 2022 introduced an intelligent system aimed at improving passenger mobility in urban transportation. This system allows users to find out the arrival times of buses near their current bus stop by leveraging smartphones, a widely accessible resource in Mexico and other developing countries.

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The system utilizes the GPS location of public transportation drivers to calculate bus arrival times near the user's stop. Experiments have demonstrated the practical utility of this mobility system in developing cities. Additionally, the system incorporates a cost-effective electronic device to monitor seat availability in monitored buses, enabling passenger count on board.

Security and privacy issues in IoT networks are becoming increasingly complex due to the need for high availability, which can compromise data security. Threats primarily focus on data routing, prompting the search for secure routing protocols, especially for vehicles connected via IoT. In their study, [92] in 2022, introduced a new cryptography-based routing mechanism to protect Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications in intelligent vehicle networks against cyber threats. This mechanism uses attribute and identity-based encryption, providing enhanced security while minimizing computational costs. To ensure message authentication, integrity, and confidentiality, a hybrid cryptography system called AIBS (Attribute-Identity Based Signature), which combines ABS (Attribute-Based Signature) and IBS (Identity-Based Signature), was successfully created and tested through simulation in the presence of potential attackers. The results demonstrate significant efficiency in terms of throughput, packet delivery rate, communication latency, and costs.

High-speed wireless communication technologies play a crucial role in establishing communication between autonomous vehicle systems (AVS) via the (IoV), significantly enhancing the efficiency and reliability of this communication. However, with the rapid growth of IoV communication, it is imperative to take measures to prevent communication disruptions and ensure the confidentiality of vehicle data. In their 2022 article [93], focused on improving real-time data security in IoV communication. They proposed a trust-based privacy method that integrates encryption and steganography. This method is based on the Encrypted and Steganographic Transmission (EAST) algorithm, which, compared to other common standards, stands out for its processing efficiency, making it a promising solution to enhance data security in the context of IoV.

The rise of the Internet has led to an increased demand for fast and cost-effective logistics, intensifying competitiveness within the manufacturing industry. The Industrial Internet of Things (IIoT) has proven essential in the era of Industry 5.0 to meet customer needs in manufacturing and logistics. This work conducted by [94] in 2022 proposed an IIoT model for logistics management. This model aims to optimize various aspects, such as logistics, customer experience, satisfaction, and transport cost reduction. It focuses on identifying optimal routes, real-time monitoring of logistics vehicle parameters, including fuel levels and engine vibrations. It also ensures temperature monitoring, designs personalized and efficient maintenance schedules, and enables predictive maintenance to increase operational efficiency. The results obtained reveal a significant improvement in the model's performance, increasing from 77% to 98%. This improvement comes with greater customer satisfaction, improved process efficiency, reduced operating costs, enhanced energy efficiency, and low-latency performance within the new IIoT-based framework.

In Saudi Arabia, road accidents have reached alarming proportions, resulting in human losses, injuries, and significant financial costs. Early detection of these accidents is crucial to saving lives, but delays can sometimes occur. Additionally, ensuring the security of sensitive data and privacy protection is a major priority when it comes to using (IoT) devices. To address these issues, the authors of the article [95] in 2023 have developed a secure IoT system for instant accident detection. This system emphasizes driver safety and privacy by using elliptic curve encryption to transmit messages via the GSM network. The results of this study demonstrate that this system can be flexibly adapted to meet other IoT security and sensitive information protection needs.

Security is a major challenge in the context of the (IoT) and (IoV), significantly hindering their adoption. Particularly in the field of the (IoV), security is crucial, especially with the advent of connected autonomous vehicles (CAVs) aimed at ensuring safe and smooth driving. Connected vehicles are vulnerable to various cyber threats, including Distributed Denial of Service (DDoS) attacks and attacks targeting single points of failure. These attacks can compromise the security and privacy of connected vehicle systems. To address these issues, the researchers in the article [96] in 2023 have designed a secure communication system based on blockchain technology for autonomous connected vehicles. This system aims to ensure secure communications while preserving the privacy of vehicles and their occupants. The article highlights the crucial importance of security and privacy in the

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field of autonomous connected vehicles and proposes a blockchain-based solution to address these challenges. Tests have been conducted to evaluate its effectiveness against DDoS attacks.

The Emergency Management System (EMS) holds a vital role in Intelligent Transportation Systems, ensuring that Emergency Vehicles (EVs) can respond quickly to incidents. However, delays caused by increasing traffic congestion in urban areas lead to serious consequences. Existing methods aim to modify traffic lights to facilitate the passage of EVs, but they do not consider the disruptions they may cause to other vehicles or the possibility of adjustments along the route. In a recent article [97] in 2023, researchers proposed a priority-guided incident management system for Unmanned Aerial Vehicles (UAVs) to improve EV response times. This model considers potential disruptions and adjusts traffic lights to minimize disruptions while ensuring a fast arrival of EVs at the incident scene. Simulations show an 8% reduction in EV response time and a 12% improvement in the time required to clear the area around the incident site.

In their recent article [98] in 2023, the researchers studied the behavior of nodes in a cloud-assisted Intelligent Transportation Network, modeling it as a cooperative hunting game. Their objective was to identify the favorable conditions for fostering cooperation among the nodes. To achieve this, they proposed an incentive-based cooperation system that provides incentives to nodes based on their roles and commitment to the network. To assess the efficiency of this methodology, the authors established a static testbed for a vehicular cloud that offers intelligent transport services, including optimal route information for vehicles. The findings of the study indicate that this approach establishes circumstances where adherence to network protocols and dedicated service to the system emerges as the most suitable and stable strategy for nodes. Furthermore, the authors scrutinized various network parameters, emphasizing performance enhancements in comparison to alternative strategies.

(AI) has been widely used to enhance autonomous decision-making in intelligent transportation systems (ITS) while addressing cybersecurity threats. However, the challenge of sharing sensitive data remains crucial. To address this issue, the use of Federated Learning (FL), a machine learning technique, ensures the confidentiality of vehicle data, while blockchain ensures data integrity. The authors of this article, [99] in 2023, applied classification techniques to detect cyber threats in connected vehicles (VANET) and (ITS). Classification models are aggregated in the blockchain and then returned to the vehicles for updates. The findings from an experimental study revealed an average decrease of 7.1% in precision and accuracy, while maintaining a comparable recall. This solution ensures the privacy protection of vehicles and data aggregation security while minimizing resource consumption.

In diverse sectors like intelligent transportation, healthcare, and emergency response, applications of the (IoT) necessitate low latency. The prevalence of these applications has surged due to ubiquitous computing, leading to the generation of substantial data that demands processing at the edge. While the cloud offers flexibility and on-demand services for efficient management of these applications, exclusively relying on the cloud, especially for latency-sensitive applications, may not be advisable. Fog computing acts as an intermediary between the cloud and IoT devices, linking sensors and devices that play a pivotal role in data storage and intermediate processing. In their 2023 article, [100], the authors introduced a strategy to enhance the reliability of the edge environment in IoT systems. This strategy, in resource allocation, considers both latency and energy efficiency. In an edge environment, users might prioritize cost-effectiveness over speed. Simulations conducted with iFogSim2 demonstrated that this new approach reduces latency by 10.3% and energy consumption by 21.85% compared to the old method.

3.4 IoT-Smart Home

The advent of blockchain technology has revolutionized decentralized management, providing an effective solution for network security and privacy. However, the lightweight, low-power, and limited memory characteristics of smart devices in the (IoT) pose challenges for their integration with blockchain. Addressing these concerns, the authors, in their 2018 article [101], devised a blockchain model based on hypergraphs. The primary objective of this model is to mitigate storage consumption and resolve various security issues. This was achieved by organizing storage nodes through hyperedges, transforming the entire data storage into partial network storage. The article extensively covers the model's design, security strategy, and illustrates its application with concrete examples within a smart home network. Furthermore, the authors conducted simulation experiments and network assessments to evaluate the storage performance of the model.

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In 2019 by [102], the authors expanded a gaze-tracking-based assistance system for smart home management and monitoring using IoT. This system, crafted by the authors, adhered to user-centered design principles and ergonomic considerations. Its primary aim was to empower individuals with disabilities to control daily home appliances such as lights, television, fan, and radio. Additionally, it offered real-time monitoring capabilities for caregivers. To optimize user-friendliness, a dedicated user interface was created. The experiments unfolded in two phases. Initially, the assistance system was deployed in a real residence, undergoing tests with 29 able-bodied participants. Subsequently, a disabled end-user engaged in a seven-day testing period, inclusive of online monitoring, conducted in their home for convenience and comfort. This approach allowed the assessment of the system in an environment reflective of its intended use. The evaluation aimed to gauge the effectiveness of the assistance system, the disabled participant's learning proficiency, and the efficiency and user-friendliness of the proposed user interface.

The article authored by [103] in 2019 presented a smart home system built on the (IoT). This system comprises a mobile application and a virtualized cloud server. It relies on several essential components, including a detection network using the ZigBee wireless communication protocol, a queuing mechanism for telemetry of messages, a virtualized cloud server, and a mobile application. The ZigBee wireless detection network is utilized by a Raspberry Pi development board to collect data from terminal sensors. Subsequently, this data is placed in a queue and processed by a telemetry transport broker, and then published on the virtualized cloud server. This seamless integration between hardware and software in the system allows for efficient data analysis and management, thereby meeting the users' needs with greater ease and convenience.

An (IoT)-based system was created for homes catering to the needs of the elderly and individuals experiencing partial memory loss, including patients with Mild Cognitive Impairment (MCI) and dementia. The researchers in the 2020 article authored by [104], presented this system designed to ensure the safety of these individuals by providing early alerts to help them manage daily issues related to these disorders. The system uses a series of ambient sensors to continuously collect data and detect contextual activities of the residents. This enables inconspicuous tracking of patients' activities at home, and essential information is relayed to family members or caregivers. Moreover, an emergency bracelet is incorporated to manage exceptional and hazardous scenarios, such as unforeseen falls, devices left unattended, or gas and water leaks in the residence. To summarize, this prototype provides an affordable solution, priced at under $100, featuring minimal energy consumption and straightforward integration. It plays a crucial role in enhancing the quality of life and safety for the elderly and individuals dealing with memory disorders.

In their article published in 2020, [105] they introduced wearable altimetric sensors based on the (IoT) designed for use by the elderly. These sensors are designed to deduce fall incidents using classification methods. Often, people lean over to reach something, which can lead to dangerous falls if they are not careful. The authors proposed specific temporal inference models, called CM-I and CM-II, for stochastically identifying fall events that could result in serious injuries or even death. To evaluate the effectiveness of these models, researchers analyzed real and synthetic data related to fall and tilt incidents. The results showed promise for integrating these inference models into the healthcare field to monitor falls in elderly individuals in smart homes. Clinical physicians could receive early alerts and anticipate fall incidents by incorporating these models into wearable IoT devices.

In their 2021 article [106], they introduced an energy management system for smart homes. This study examined future research possibilities to ensure that smart homes are energy-efficient, thereby avoiding unnecessary energy consumption, health issues, and cybersecurity vulnerabilities. However, the study's results revealed a lack of certain essential qualities, including security, privacy, scalability, and interoperability. Furthermore, it was found that managing and adapting to residents' thermal comfort poses significant challenges, exposing them to potential health risks.

In their 2022 article, [107] introduced a fuzzy framework for Smart Home Monitoring Systems (FF-SHMS) using the (IoT), demand monitoring, green energy conservation, and microgrids to achieve energy savings. This fuzzy framework proposes an architecture aimed at optimizing the construction of smart microgrids, taking sustainability factors into account and regulating loads based on available resources. By using renewable energy sources and optimizing the economic reward of microgrids, this fuzzy framework aims to improve the utilization of electricity and storage. It enables both controlled and uncontrolled energy efficiency by considering parameters such as solar power, wind speed, and electrical load. The results obtained through this expert approach include the management of energy consumption and production of microgrids.

Security and user privacy are critical concerns in the realm of smart homes. While these homes have the potential to enhance home life, drawing inspiration from the principles of smart cities, the risk of compromising Conveyed information by hackers is heightened when accessing smart home systems via public channels. In response to this challenge, the authors of the 2023 article [108], introduced an Authentication and Key Agreement (AKA) scheme tailored specifically for smart home environments. This scheme relies on the use of a gateway that facilitates the connection and communication between different networks and devices. Additionally, they integrated SGX (Software Guard Extensions) technology, widely used in areas such as data security, privacy, and intellectual property protection, to effectively prevent internal attacks. The costs associated with the security, computation, and communication of this scheme were analyzed in comparison to existing schemes, and the result shows that this system performs more optimally in this environment. Regarding future perspectives, the authors recommend that authentication schemes for smart homes incorporate multiple methods, including biometrics and multi-factor authentication. Furthermore, they encourage users to restrict access to their smart home devices by creating strong passwords to enhance the security of their data.

3.5 IoT-Smart City

In their article published in 2019, [109] offered a concise overview of various smart city initiatives. They highlighted the numerous critical challenges that cities face due to rural-to-urban migration worldwide, including areas such as education, healthcare, transportation, energy, waste management, unemployment, and crime control. The author emphasized the essential role played by Information and Communication Technologies in the transformation of conventional cities into smart cities. They additionally established a correlation between the (IoT) and the attributes of smart cities, extending this connection further by outlining a futuristic scenario grounded in IoT to enhance waste management processes within the framework of smart cities.

Fog computing and the (IoT) are instrumental in shaping smart cities, enabling the effective management and exchange of urban information. The establishment of smart cities contributes to the expansion of urban businesses, the industrial sector, the transportation industry, and enhances tourism management. In a 2020 article [110], the significance of emerging network technologies, specifically Fog Computing and the IoT, is emphasized concerning the advancement of smart cities. These technologies are regarded as essential assets for the comprehensive advancement of the city. The article meticulously explores the benefits of Fog Computing and proposes an architecture that integrates the Internet of Things with this technology to efficiently tackle network scalability and process vast amounts of data.

Applications utilizing the (IoT) through cloud integration offer substantial potential for enhancing smart cities. They facilitate the gathering of data from diverse sources like citizens, devices, and residences, creating numerous prospects for optimizing urban services. In a 2021 [111], the author explores the fusion of the IoT with the cloud, spotlighting IoT solutions that leverage cloud infrastructure for the storage, management, and analysis of collected data. The article also provides tangible instances of cloud-based IoT applications within the realm of smart cities, illustrating how these technologies can enhance citizens' quality of life and urban resource management. Moreover, the author underscores the prospect of novel applications emerging through ongoing research and encourages contemplation of their significance in the continually evolving landscape of smart cities.

The waste management methods based on the (IoT) have been thoroughly studied. Researchers observed that various digital energy techniques had been implemented to improve the energy efficiency of sensors, but none of them had comprehensively addressed the issues related to energy consumption and optimization. Furthermore, the authors proposed a second contribution related to a data collection method for waste management within the framework of smart cities, employing the (IoV). Moreover, the article written in 2022 by [112] suggests the use of swarm intelligence-based techniques to enhance energy efficiency and collect data for waste management applications in smart cities. Ultimately, the article presents an eco-friendly opportunistic model that leverages ant-based routing algorithms for low-power wireless sensor networks, especially in the context of waste management within smart cities. Additionally, analytical methods are discussed to

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evaluate the energy consumption of the network model.

Sustainability-focused cities aim to reduce their carbon footprint and environmental impact. To achieve this goal, IoT-enabled smart cities are a natural approach. Nevertheless, the widespread adoption of sensors and IoT technologies has given rise to the requirement for streamlined ontological models tailored for IoT environments, exemplified by IoT-Stream, facilitating real-time data annotation. While the IoT-Stream model is based on sharing semantic knowledge and simplifying queries and inferences, it does not allow for in-depth analysis of sensor characteristics and application domains. In a 2023 article [113], the authors introduced a taxonomy of sensors, an extension of the original IoT-Stream model. This extension facilitates the mapping of sensors, actuators, and services within the context of smart cities. Such an approach serves to avert unnecessary duplication of sensors and network infrastructure, fostering seamless information exchange across various applications.

Table 2: Related Work on the Internet of Things in Various Domains.

DOMAIN	*PROBLEMATIC*	*METHODE*	*DESCRIPTION*
AGRICUL [8]	Soil moisture is insufficient, thereby contributing to the optimization of water usage.	• IoT	A crop monitoring system using soil sensors has been proposed to automate irrigation when soil moisture is low, thus optimizing water usage. The sensors are connected to a Raspberry Pi, enabling wireless communication. The results demonstrate that this project effectively addresses agricultural irrigation issues.
AGRICUL [9]	Manual tests are time-consuming and impractical due to the constant variations in water quality measurement parameters. It is better to opt for automated monitoring.	• IoT Sensors	This system, which employs Raspberry Pi, Arduino, sensors, smartphone cameras, and Android apps, monitors water quality in aquaculture. It measures temperature, pH, conductivity, and color. Arduino collects sensor data, Raspberry Pi processes it, and serves as a server. Smartphone cameras linked to Raspberry Pi detect water color. Android apps enable remote water monitoring, analysis, and necessary actions. This cost-effective approach outperforms other existing systems.
AGRICUL [10]	The LoRaWAN system is specially designed to meet the requirements of agricultural activities involving numerous sensors that generate data streams for analysis.	• IoT • LoRaWAN Network	The IoT agricultural system utilizes the LoRaWAN network to efficiently transmit data over long distances from sensors to cloud services while conserving energy.
AGRICUL [11]	Inefficient methods, the need for a large workforce, and the management of irrigation and fertilizers.	• IoT	IoT enhances agriculture through soil and temperature monitoring sensors, integrating them with traditional farming practices to create smart agriculture. This approach collects environmental data and enhances predictive capabilities, revitalizing the agricultural sector by streamlining processes, promoting intelligent farming, and simplifying farmers' lives with minimal intervention.
AGRICUL [12]	Transmission delays of agricultural data have a limited impact on production.	• IoT • Wi-Fi, ZigBee, and Bluetooth.	They explored different wireless technologies for creating IoT devices. Some, like ZigBee, Wi-Fi, and Bluetooth, can work in similar frequency ranges. While Wi-Fi offers high-speed data transfer, it's power-hungry and may not suit low-power sensors. Bluetooth, on the other hand, is

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			secure but has range and power consumption limitations.
AGRICUL [13]	Simplifying farming practices by providing farmers with essential nutrients through real-time field monitoring. User data on demand and costs ensure the production of high-quality products at reasonable rates.	• IoT	The analysis of IoT architecture aims to infuse intelligence into the agricultural domain by merging data from sensors, actuators, and farmers. The shared information leads to recommendations for optimizing agricultural practices' efficiency. Concrete examples illustrate the relevance of this architecture in various agricultural contexts.
AGRICUL [14]	The challenges associated with the use of potentially harmful pesticides, irrigation management, pollution reduction, as well as the environmental consequences of agricultural practices.	• IoT • AI • ML • DL	These technological advancements address agricultural issues such as crop diseases, stock management, pesticide regulation, weed control, inadequate irrigation, and water management. The article emphasizes the significance of tackling problems related to harmful pesticides, ineffective irrigation, pollution, and environmental impact.
AGRICUL [15]	The use of (IoT) and (AI) technologies has the potential to bring about a positive transformation in traditional agriculture.	• IoT • AI	Exploring the impact of recent computer technologies, like AI and the IoT, in the agricultural sector can lead to an enhancement in production by integrating these innovations with traditional farming methods.
AGRICUL [16]	The future of agriculture, aiming for intelligence and efficiency, depends on adopting diverse technologies, especially digital ones.	• IoT • Cloud Computing • UAV • Wireless Sensors	The article discusses sensor and IoT technology in agriculture, including wireless sensors, drones, and cloud computing. It also examines IoT architectures and platforms for farming applications, addressing current challenges and future opportunities.
AGRICUL [17]	The system aims to notify farmers of nitrogen, phosphorus, and potassium deficiencies in the soil by sending SMS notifications.	• IoT • NPK Sensor	An IoT-based system with a unique NPK sensor, using LDR and LEDs, assesses soil N, P, and K levels. It alerts farmers about fertilizer amounts through an inference method. The hardware prototype and microcontroller software were created with Python.
AGRICUL [18]	Assisting stakeholders (farmers, factories, government) in collecting and analyzing changes in sugarcane production.	• IoT	A smart monitoring system for the sugarcane industry, based on the (IoT), allows for resource prediction., damage reduction, moisture traceability, and waste minimization in a collaborative framework. The study aimed to validate the model using real-time data for future research.
AGRICUL [19]	This system enables precise irrigation to manage water needs, correct sprinkler issues, and identify plant diseases and pests.	• IoT	An innovative system near agricultural irrigation pivots uses wireless sensors and Kubernetes to collect real-time environmental data, allowing for precise water requirement updates every 5 minutes based on measurements from a shared weather station and crop-specific coefficients.
AGRICUL [20]	To address security and performance issues in IoT-based agricultural systems.	• IoT • Blockchain	They studied blockchain in IoT-based agriculture for precision farming, focusing on food supply chains, livestock management, and crop monitoring. The analysis considered different blockchain platforms, emphasizing security and privacy. The aim is to enhance self-sufficiency, efficiency, and agricultural optimization while addressing obstacles to the advancement of blockchain-IoT systems in

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			precision agriculture.
AGRICUL [21]	The adoption of detection systems, artificial intelligence (AI), and the Internet of Things (IoT) to efficiently monitor and manage automated processes.	• IoT • AI	The involvement of these technical experts in automation, IoT, and intelligent systems in the field of aquaponics has facilitated the understanding of automation specialists regarding the biological processes specific to aquaponic systems. This collaboration aims to develop and scale up aquaponic systems, accelerating progress in this field and strengthening commercial solutions.
AGRICUL [22]	This innovation enhances the lives of farmers with an effective management and monitoring tool for their crops and resources.	• IoT Server • Wi-Fi Model • GSM Modem	They've introduced a smart agricultural monitoring system for farmers, using wireless sensors for data collection on parameters like temperature, humidity, and water levels. The system sends alerts via SMS in case of anomalies and allows remote monitoring and control via the Internet. It utilizes sensors, a camera, and a microcontroller for data transmission to an IoT server in a graphical format.
AGRICUL [23]	IoT applications are set to revolutionize agriculture through innovative technologies for monitoring, operation, and the organization of crop and livestock production cycles.	• IoT • AI	They have introduced a comprehensive AI concept for agriculture that utilizes independent AI modules connected via a cloud network. This approach brings together users, suppliers, and computer experts, promising to enhance the efficiency and sustainability of the agricultural sector.
AGRICUL [24]	Monitoring and spraying of Precision Agriculture (PA) crops.	• UAV	They examined Precision Agriculture (PA) and the use of (UAVs). Subsequently, they assessed the applications of UAVs for crop monitoring and spraying. An evaluation of the UAV architecture is ongoing to determine if it involves a single device or multiple UAVs. This also includes an analysis of methodology, UAV type, technical specifications, and payload.
AGRICUL [25]	The study on IoT and big data in agriculture includes greenhouse monitoring, smart farming equipment, and crop-imaging drones. These technologies drive supply chain modernization, open innovation via social media, food industry sentiment analysis, food product quality assessment, and sensor data integration.	• IoT • AI • Blockchain • Big data	The review focuses on food security through genetic sequencing and blockchain-based digital traceability. IoT, big data, and AI advancements have become commonplace, emphasizing the importance of adopting and effectively using these innovations for success in agriculture and the food industry.
AGRICUL [26]	Seedling growth rates are contingent on the ambient environment. To meet delivery deadlines, quality standards, and reduce energy costs, IoT control of greenhouse equipment is essential.	• IoT	The proposed system employs IoT to connect devices with each other. It utilizes a hierarchical control process for long-term planning at the higher level and makes hourly decisions at the base level. This system uses a crop growth model, real-time data collected by IoT sensors, and historical data stored in a database to make intelligent decisions for greenhouse management.

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AGRICUL [27]	To integrate digital technologies into agriculture and develop AI and IoT-based solutions in this sector.	• IoT • AI	They have examined recent research in agriculture with a focus on digital technology to identify key applications of agricultural engineering utilizing AI and the IoT. The article delves into the technical specifics of artificial intelligence, the Internet of Things, and the barriers to their adoption.
AGRICUL [28]	To promote the well-being of aquatic organisms, monitoring measures various parameters such as pH, light, temperature, water level, ammonia, electrical conductivity, and so on.	• IoT • AI • MQTT protocol • Sensor NodeMCU.	They've introduced an aquaponic system with sensors, making use of the Grove expansion board for sensor connectivity to the NodeMCU, facilitating MQTT integration with Home Assistant and OpenHAB. This solution enables monitoring, control, and parameter correlation through IoT and AI, offering an interoperable, secure, scalable, cost-effective, autonomous, flexible, reliable, and generic IoT solution for aquaponics.
AGRICUL [29]	The challenges of smart agriculture include IoT device computational power, early AI-based disease detection, crop water stress monitoring, soil condition assessment, livestock disease tracking, and understanding agricultural behavioral patterns.	• IoT • AI	Agriculture has evolved significantly, enabling farmers to remotely monitor their farms via smartphones and manage various equipment. Furthermore, the use of genetically modified seeds has improved the quality and quantity of production. An intelligent IoT system could reduce food waste, increase production, and provide valuable insights in agriculture.
AGRICUL [30]	The intelligent system for cage farming operations utilizes AI and IoT to address significant challenges and promote large-scale development in cage farming.	• IoT • AI • Big data	They introduced a data system connecting fields to a cloud platform for cage farming improvement. Using AI and IoT, it collects data for fish health, survival, and food remnants, enabling farmers to reduce waste and enhance food efficiency while tracking fish growth and survival rates.
AGRICUL [31]	Monitoring and issue detection in water, remote pump alerts and control, fish disease detection, and a digital community for fish farmers to enhance their operations, increase their income, and integrate data.	• IoT • AI • MQTT Protocol • Wi-Fi Model • ML	They have proposed an intelligent solution using IoT and machine learning (ML) to manage fish farms. They utilize components such as Arduino Mega, ESP32, C programming language, WiFi, and MQTT protocol to collect and transmit real-time data from fish farms to farmers' smartphones. A convolutional neural network is employed to classify fish diseases.
AGRICUL [32]	The (IoT) plays a crucial role in addressing challenges in agricultural technology and various other applications.	• IoT • AI • UAV	They have explored the integration of IoT with AI-controlled drones and robots, while also identifying their limitations in developing countries. The success of smart agriculture relies on the speed of data transfer.
AGRICUL [33]	However, there are issues related to energy, data security, cost, interoperability, and food quality associated with the control and monitoring of the agricultural environment.	• IoT • AI • ML	Agriculture has evolved significantly, enabling farmers to remotely monitor their farms via smartphones and manage various equipment. Furthermore, the use of genetically modified seeds has improved the quality and quantity of production. An intelligent IoT system could reduce food waste, increase production, and provide valuable insights in agriculture.

AGRICUL [34]	Food security presents a significant challenge, and water quality plays a crucial role in the success of aquaculture, making real-time monitoring of its quality imperative.	• AI • LoRa (Long Range) wireless • ML	An affordable AI buoy system with RS-485 for stable sensor measurements and LoRa wireless communication for long-distance data transfer to a coastal server predicts water quality, temperature, and speed using machine learning. It also creates a cost-effective flow meter from flow sensor data. The buoy collects water data to estimate feeding needs for sea cages, reducing waste and feeding costs while minimizing ocean pollution.
AGRICUL [35]	Significant Problem: Evaluating the weight and mass of fish in aquaculture is crucial for determining the best time for harvest. However, this often requires extended manual handling, which can lead to significant stress for the fish.	• AI	An AI-driven non-invasive method identifies, measures, and weighs fish without manual handling, reducing stress and saving time, especially amid changing environments or fish species. Its growing use improves production control by accurately measuring fish weight and length through automatic detection using filtered infrared light, also allowing future weight estimation.
AGRICUL [36]	The (IoT) is crucial for smart agriculture and combating climate change. This technology connects billions of smart devices that streamline automated management and monitoring in these fields.	• IoT • AI • Blockchain • ML	They've combined advanced tech like IoT, AI, ML, and blockchain for Climate-Smart Agriculture (CSA), aiming to automate agrotechnologies for sustainability, efficiency, and environmental protection. The article explores CSA, its concepts, and applications, proposing an approach that integrates IoT, ML, and blockchain to strengthen CSA. This helps farmers and experts effectively utilize these smart agri-tech to address sustainability and climate change challenges.
AGRICUL [37]	Aquaponics is an innovative and eco-friendly agricultural technique that synergistically combines aquaculture (fish farming) with hydroponics to cultivate vegetables. It promotes the production of healthy organic food while reducing water consumption and the use of chemical fertilizers.	• IoT	They conducted a detailed review of research on automated aquaponic systems, covering various parameters and proposing scenarios for IoT-based smart automation. They used real-world examples and research findings, highlighting potential research gaps and future contributions. These studies suggest that aquaponic systems with intelligent control units can become more cost-effective, intelligent, precise, efficient, and economically sustainable.
AGRICUL [38]	The challenge of automated smart farming is to enhance black soldier fly (BSF) farming while minimizing food losses.	• IoT	They have established an automated agricultural system for BSF farming using IoT. This allows remote monitoring of the farm and real-time adjustments, emphasizing the potential of smart agriculture in large-scale BSF farming for producing larvae used in organic waste management and valuable compound production. BSF larvae are rich in bioactive compounds, providing numerous applications.
AGRICUL [39]	To develop smart aquaculture, it is crucial to identify fish biodiversity and monitor their real-time behavior to optimize food management.	• DL	They developed an efficient CNN for classifying fish behavior into two categories: normal and starvation, in smart aquaculture. Different layer configurations were tested, and adding three of these layers with max-pooling improved the detection accuracy by 10%. The results demonstrate that the model addresses the issue of poor generalization in shallow neural networks, achieving a 98% accuracy in fish image classification.

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AGRICUL [40]	In agriculture, the (IoT) combined with (UAVs) and (WSNs) provides significant opportunities for aerial crop monitoring and smart, cost-effective spraying solutions.	• IoT • Wireless Sensor (WSN) • UAV • AI	The authors presented a study on the potential use of UAVs in Precision Agriculture (PA), examining recent developments in integrating UAV sensor systems and AI algorithms in PA applications. They also discussed the challenges and future prospects for the development of these technologies.
AGRICUL [41]	The challenge is to assess and provide the optimal performance of a greenhouse system within the context of smart agriculture.	• Blockchain	The authors propose a three-step blockchain approach to improve greenhouse systems, including prediction, optimization, and control. They use the Kalman filtering algorithm to predict sensor data and adjust environmental parameters to manage actuators for maintaining desired conditions. An emulation tool demonstrates a 19% energy consumption reduction compared to forecasts and a 41% reduction compared to the reference method.
AGRICUL [42]	The issue enhances the security of agricultural environments through IoT, thereby promoting safer and more reliable precision agriculture.	• IoT • Blockchain • Cloud Server	The AKMS-AgriIoT is a blockchain-based solution that enhances security in IoT, particularly in Smart Precision Agriculture (SPA). It utilizes a private blockchain for secure communication between smart devices, drones, and servers. This system provides superior security, additional features, and cost-efficiency. It excels in balancing security and features with communication and computation costs when compared to other solutions.
AGRICUL [43]	The challenge of smart aquaculture monitoring to predict the growth of California Bass fish can be addressed through intelligent management systems.	• IoT • AI • DL • Wifi Model	Authors present an IoT and AI-based smart aquaculture monitoring system for California Bass fish growth prediction. It collects and analyzes data using deep learning, integrated into a self-sustained feeding system, preventing food waste. The model accurately predicts 52-week fish growth with R2 0.94 and mean squared error 0.0015 during validation.
AGRICUL [44]	The challenge in cattle farming is to ensure animal well-being and improve livestock management accuracy.	• IoT • RFID • GPS	The study explores IoT and Digital Twin technology (DTLF) in cattle farming, emphasizing automated tracking and health monitoring. They used GPS, RFID, and computer vision for animal tracking and developed a prototype for real-time data collection. The system updates a website with data like animal temperature and location, aiming to enhance animal well-being and breeding precision, assessing parameters such as efficiency, disease detection, and more.
AGRICUL [45]	The challenge of planning and monitoring irrigation for tomato and eggplant crops.	• IoT • LoRa (Long Range)	The authors introduced a LoRa-IoT solution for smart irrigation, reducing water consumption by 46% compared to traditional methods for tomatoes and eggplants. It maintains plant health, provides remote soil monitoring, and efficient data storage via IoT. This improves irrigation management and offers remote monitoring of soil and weather data, enhancing agricultural efficiency.

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AGRICUL [46]	Integrating BFT with other technologies is vital to improve aquaculture sustainability and address pollution, high costs, and low productivity in traditional aquaculture.	• IoT	The review examines integrating biofloc technology (BFT) into aquaculture's future. BFT offers innovative solutions for traditional aquaculture challenges. It optimizes parameters and combines Fourth Industrial Revolution technologies like ICT and IoT for real-time monitoring, enhancing aquatic organism health and automating aquaculture tasks.
AGRICUL [47]	The challenge is monitoring and optimizing fish farms by controlling key parameters to enhance long-term productivity.	• IoT • AI	They analyzed a literature review on sustainable productivity in freshwater and inland aquaculture, focusing on the use of information and communication technologies (ICT), such as IoT and AI. These technologies are utilized in various areas including water quality, fish feeding, water recirculation, fish transportation, traceability, and fish welfare. Real-world studies are needed to assess the impact of AI on freshwater fish farming. To achieve credible results, global research collaboration is required, leveraging ICT tools for progress.
DOMAIN	ProblematiC	Methode	Description
AGRICUL [48]	The challenge is real-time monitoring of environmental conditions for success and efficient water quality control in ponds to preserve fish health.	• IoT • ThingSpeak Cloud • ML	The authors created an IoT system to monitor water quality in ponds, aiming to preserve fish life. They found that ponds 1, 3, and 4 are suitable for fish farming due to optimal conditions, while ponds 2 and 5 require machine learning support. The Random Forest algorithm demonstrated high accuracy at 94.42%, a kappa coefficient of 93.5%, and a 94.4% true positive rate. Data is stored in the ThingSpeak cloud.
AGRICUL [49]	The challenge is effectively using digital twins for precise simulation, analyzing physical systems, and enabling remote monitoring and control while efficiently handling data from various sources.	• IoT • AI • DL • ML	Researchers are advancing AIoT in aquaculture, utilizing big data, digital twin, and AI for fish farm management. AI-driven ML and DL analyze data for informed decision-making and enable real-time remote monitoring. This innovative approach combines digital twin and AI for smart aquaculture in marine environments.
AGRICUL [50]	To ensure efficient aquaculture in Taiwan's vital economy, precise monitoring of Dissolved Oxygen (DO) in fish ponds is essential.	• IoT • Recurrent Neural Networks (RNN)	The authors developed an efficient IoT system with AI and RNN for water quality monitoring. Their 7-layer GRU model excelled in performance. This system, in partnership with Taiwan's Institute of Industrial Technology and a local fishing company, improves fish farm survival by maintaining oxygen levels. It offers automated, secure, energy-efficient, and reliable pond monitoring.
HEALTH [51]	The issue at hand revolves around the vital role of IoT in data collection and monitoring, along with the role of AI in data analysis and decision-making.	• IoT • AI	The authors discussed healthcare applications in wearables, disease detection, patient care, and sensor networks, underscoring their potential benefits. However, the success of IoT and AI healthcare applications relies on technology adoption, stringent data security rules, and enhanced system efficiency and safety.

HEALTH [52]	The study's issue revolves around the security of IoT devices in the healthcare sector.	• IoT • ECG	The researchers created an advanced security system for healthcare IoT devices, utilizing ECG-based key generation and secure authentication via DTLS. Tests confirmed the efficiency of ECG-based key generation in terms of speed and energy use. Their approach reduced communication overhead by 26% and lowered latency by 16% compared to existing methods. This solution prioritizes secure IoT healthcare communication while optimizing costs. Future research will explore the trade-offs between security, latency, and energy consumption.
HEALTH [53]	This study's focus is on assessing the performance of NB-IoT (Narrowband Internet of Things) technology in the context of medical monitoring.	• NB-IoT (Narrowband Internet of Things)	The authors introduced NB-IoT (Narrowband Internet of Things) for long-range, low-data-rate communication, suitable for sensors with low processing complexity and extended battery life. They assessed its performance in medical monitoring, considering SND (Single Number Density) and MND (Multiple Number Density). Findings indicated that the MND approach enhanced throughput and patient capacity per cell, with a minor increase in latency due to reduced control information overhead. In summary, optimizing throughput, latency, and device density is essential for adapting the solution to various use cases.
HEALTH [54]	The problem is about implementing IoT in healthcare with Cloud Computing, which poses challenges related to latency, data management, user expectations, and diverse applications.	• IoT • Cloud Computing • Fog Computing	The authors introduced Fog Computing solutions that enhance proximity to data sources. Ensuring Cloud-Fog interoperability demands complex application coordination and smart service orchestration for optimized resource use while maintaining stability, service quality, and security. They proposed a superior Fog-based IoT-Healthcare solution evaluated through iFogsim simulations, demonstrating improved service distribution, cost reduction, energy efficiency, and decreased network latency.
HEALTH [55]	The article discusses integrating the Cloud-IoT model into healthcare, creating opportunities for medical technologies, improving healthcare services, and driving innovation.	• IoT • Cloud Computing (CC)	The article thoroughly examines the integration of Cloud-IoT in healthcare, including smart hospitals, medication management, and telehealth. It assesses the current status, identifies areas needing improvement, reviews prior research, outlines challenges, and proposes future research directions, supported by an extensive bibliography.
HEALTH [56]	This article discusses creating a non-invasive IoT solution for healthcare, using Bluetooth Low Energy (BLE) technology in a wearable device to monitor vital signs.	• IoT • Bluetooth Low Energy (BLE) • (ECG) and (PPG) • PVDF film Sensor	The authors developed a healthcare IoT solution that combines a device with a smart terminal. This innovation utilizes a wrist-worn PVDF film sensor to detect cardiac vibrations and calculate heart rate from radial artery signals. This approach improves energy efficiency and accuracy by optimizing SNR through a filtering circuit and peak detection algorithm. The collected data is sent to the cloud for real-time monitoring of users' vital signs and emergency access for medical facilities.
HEALTH [57]	The challenge is to design a blockchain model suitable for the (IoT) for Remote Patient Monitoring (RPM) while ensuring high privacy and security.	• IoT • Blockchain	New blockchain model enhances IoT-based Remote Patient Monitoring (RPM) for home healthcare. Emphasis on lightweight design, privacy, and security by eliminating proof of work. Components: blockchain network, cloud storage, healthcare providers, smart contracts, and IoT-equipped patients. Layered network enhances efficiency, reduces costs and delays while maintaining integrity.

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HEALTH [58]	The challenge is the rising use of IoT in healthcare, which brings benefits but also exposes medical devices to potential vulnerabilities and threats, jeopardizing patient safety and healthcare security.	• IoT	The study develops a healthcare-specific IoT security risk management model, with a case study in a Malaysian government hospital. It incorporates performance indicators and implementation phases to ensure secure and beneficial IoT solutions in healthcare.
HEALTH [59]	The challenge is ensuring reliable healthcare processes with IoT devices, like biomedical sensors and patient tags, which are vital for patient health. Consideration of factors like reliability, availability, and cost is essential in modeling and executing these processes.	• IoT	The article emphasizes ensuring IoT-connected BPMN healthcare processes' reliability using the SWR method. It suggests extending BPMN to incorporate reliability data, enabling informed design, enhanced participant selection, service execution, and process monitoring. Particularly relevant for assisted living systems, the article offers a comprehensive solution to assess reliability in IoT-integrated BPMN healthcare processes.
HEALTH [60]	The challenge is to create an IoT-based healthcare monitoring system for continuous tracking of patients' physiological parameters.	• IoT • Wi-Fi connectivity	The authors presented a continuous monitoring tool using Wi-Fi to store patient data on a server. They introduced an IoT-based healthcare monitoring system, enabling authorized medical personnel to remotely access and diagnose patient data collected via sensors and transmitted to a medical server and personal smartphones with IoT platforms.
HEALTH [61]	The challenge is the implementation of the (IoT) in the healthcare sector, specifically using Wireless Body Area Networks (WBAN) to monitor patients' vital signs.	• IoT • Wireless Body Area Network application (WBAN)	The authors developed a WBAN-based patient monitoring app, ensuring reliability and data accuracy. The interconnected modules with pulse oximeter sensors wirelessly transmit data to a central database, enabling custom alerts. Tests confirmed system reliability and minimal interference with other 2.4 GHz systems, ensuring smooth operation.
HEALTH [62]	The challenge is IoT monitoring of medical parameters using wearable or implanted sensors with limited battery life, raising concerns about energy efficiency and network sustainability.	• IoT • An Energy-Efficient Routing Protocol: (PEERP)	They introduced PEERP, an Energy-Efficient Priority-Based Routing Protocol for Reliable Healthcare Data Transmission via IoT. It classifies health data into Emergency and Vital categories, with different communication methods. Simulations show improved sensor energy efficiency, extending network life and ensuring reliable data delivery.
HEALTH [63]	The challenge is the use of Fog Computing in healthcare, especially in the context of the (IoT).	• IoT • Fog Computing	Researchers presented a Fog Computing-based platform to reduce latency and improve healthcare services, crucial for healthcare projects. Reducing data transmission costs to the cloud is a key research objective.
HEALTH [64]	The challenge is to develop a diagnostic model for heart diseases and diabetes using a convergence of (AI) and ML techniques.	• AI • ML	They created an advanced diagnostic model for intelligent healthcare, utilizing (AI) and (ML), with a specific emphasis on diagnosing heart disease and diabetes. The model encompasses data acquisition, preprocessing, classification, and parameter tuning. It incorporates IoT devices and leverages the CSO-CLSTM model and iForest algorithm, resulting in an impressive 96.16% accuracy in diagnosis.

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HEALTH [65]	The challenge is to use the Internet of Things (IoT) to develop COVID-19 diagnostic, assessment, and treatment procedures in sustainable smart cities.	• IoT	The researchers emphasize IoT's vital role in reducing contagion in sustainable smart cities, focusing on healthcare applications, security, and reliability. They identify challenges, outline future research, and explore increased IoT adoption for COVID-19 response to enhance productivity and reduce costs.
HEALTH [66]	The challenge is leveraging emerging technologies, including IoT and AI, in Smart Cities to enhance healthcare and reduce costs.	• IoT • AI • ML	IoT and AI are essential for improving healthcare and reducing costs in Smart Cities. The research focuses on urban health monitoring, emphasizing innovation and practicality in areas like active aging, population tracking, and real-time health monitoring using IoT and ML.
HEALTH [67]	The challenge involves enhancing access to medical services in rural areas with restricted healthcare availability.	• IoT	In remote areas, an IoT-based health monitoring system was developed for conditions like COVID-19, hypertension, and diabetes. Sensors collect data (SpO2, heart rate, temperature) transmitted to a web platform. It's compact, fast, cost-effective, and useful for healthcare. Reports reach healthcare professionals for immediate action in emergencies.
HEALTH [68]	The challenge is to create EPPADA, an innovative authentication scheme that uses IoT and eco-friendly IT to meet healthcare sector needs.	• IoT	EPPADA is an efficient healthcare authentication scheme using IoT and eco-friendly tech, ensuring data privacy with homomorphic encryption. It reduces data traffic, conserving energy and extending network life. Authors tested an experimental system with E-health sensor shield V2.0, demonstrating low computation, reduced communication costs, and overhead control.
HEALTH [69]	The challenge: Urgently address digital solutions for predicting and managing emerging diseases in Bangladesh, such as COVID-19 and dengue, with significant barriers including the lack of a digital healthcare system, inadequate preparedness, and limited public awareness.	• IoT • AI	In this context, researchers propose an IoT and AI-based digital healthcare and monitoring system to enhance early detection of COVID-19 and dengue, while strengthening national control strategies.
HEALTH [70]	The focus is on exploring blockchain's potential impact on data security in IoT and healthcare.	• IoT • Blockchain	The authors stress blockchain's role in enhancing data security in various fields, including IoT, with a focus on medical IoT. They address the key question of effective blockchain adoption for data security, drug supply chain management, and real-time data sharing, particularly in smart cities.
HEALTH [71]	The challenge is the impact of 5G technology on the (IoT), especially in the realm of healthcare wearable IoT devices.	• IoT • Wearable Devices • 5G	The authors stress the pivotal roles of IoT, wearables, and 5G in healthcare improvement while addressing present vulnerabilities and forthcoming research challenges. In essence, the article centers on these technologies in healthcare, spotlighting opportunities, applications, and research hurdles.
HEALTH [72]	The challenge is to create an innovative IoT and fuzzy logic system to meet the essential needs o f	• IoT • AI	AI created an innovative system: IoT health monitoring and fuzzy logic-based diagnosis for critical patients, including COVID-19 cases in remote areas. It enables doctor-patient interaction through sensors, cloud storage, and

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	patients, particularly those with COVID-19 in remote areas.		SMS/email, aiding isolated patients. The algorithm achieves nearly 100% diagnostic accuracy in real-time ECG analysis, especially valuable for remote COVID-19 patients with severe cardiac issues requiring intensive care.
HEALTH [73]	The problem is with machine learning-based authentication models, especially their sensitivity to imbalanced datasets and the complexity of adding new users.	• ML • ECG • Siamese Network (ESN)	The authors propose an innovative approach for authentication using ECG signals and a Siamese Network ensemble (ESN). It overcomes limitations of machine learning models, achieving high precision rates of 93.6% and 96.8%, and low error rates of 1.76% and 1.69% with ECG-ID and PTB datasets. This model is ideal for smart healthcare, offering robustness, simplicity, and data accessibility, while addressing challenges related to imbalanced datasets and user integration.
HEALTH [74]	The challenge is ensuring reliable health data from IoT devices for accurate healthcare decisions and recommendations, as unreliable data can lead to incorrect decisions.	• IoT	Healthcare in the context of IoT requires dependable data. The authors suggest a trustworthy model, Health IoT Evaluation System (HIES), designed for precise circadian health decisions. This model considers factors such as device and user identity, health information, user feedback, data consensus, and acceptance. It identifies potential issues, enabling reliable monitoring and providing health recommendations based on trust.
HEALTH [75]	The challenge is to address the growing prevalence of type 2 diabetes, a severe and incurable disease that is a leading global cause of death. To combat this public health issue, implementing preventive and predictive measures is vital.	• IoT • ML • Cloud Service • Edge Computing	Diabetes, a major global cause of death, requires proactive prediction and prevention. HealthEdge, a smart health framework, uses IoT, cloud, edge processing, and machine learning to predict type 2 diabetes. Experiments demonstrate a 6% higher accuracy of the Random Forest (RF) algorithm compared to Logistic Regression (LR) for diabetes prediction. This framework anticipates type 2 diabetes through machine learning, assessing risk factors with sensors. The machine learning model is cloud-trained and deployed on edge servers for diabetes prediction, evaluated using real data and common machine learning algorithms.

HEALTH [70]	The focus is on exploring blockchain's potential impact on data security in IoT and healthcare.	• IoT • Blockchain	The authors stress blockchain's role in enhancing data security in various fields, including IoT, with a focus on medical IoT. They address the key question of effective blockchain adoption for data security, drug supply chain management, and real-time data sharing, particularly in smart cities.
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HEALTH [72]	The challenge is to create an innovative IoT and fuzzy logic system to meet the essential needs of patients, particularly those with COVID-19 in remote areas.	• IoT • AI	AI created an innovative system: IoT health monitoring and fuzzy logic-based diagnosis for critical patients, including COVID-19 cases in remote areas. It enables doctor-patient interaction through sensors, cloud storage, and SMS/email, aiding isolated patients. The algorithm achieves nearly 100% diagnostic accuracy in real-time ECG analysis, especially

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HEALTH [73]	The problem is with machine learning-based authentication models, especially their sensitivity to imbalanced datasets and the complexity of adding new users.	• ML • ECG • Siamese Network (ESN)	The authors propose an innovative approach for authentication using ECG signals and a Siamese Network ensemble (ESN). It overcomes limitations of machine learning models, achieving high precision rates of 93.6% and 96.8%, and low error rates of 1.76% and 1.69% with ECG-ID and PTB datasets. This model is ideal for smart healthcare, offering robustness, simplicity, and data accessibility, while addressing challenges related to imbalanced datasets and user integration.
HEALTH [74]	The challenge is ensuring reliable health data from IoT devices for accurate healthcare decisions and recommendations, as unreliable data can lead to incorrect decisions.	• IoT	Healthcare in the context of IoT requires dependable data. The authors suggest a trustworthy model, Health IoT Evaluation System (HIES), designed for precise circadian health decisions. This model considers factors such as device and user identity, health information, user feedback, data consensus, and acceptance. It identifies potential issues, enabling reliable monitoring and providing health recommendations based on trust.
HEALTH [75]	The challenge is to address the growing prevalence of type 2 diabetes, a severe and incurable disease that is a leading global cause of death. To combat this public health issue, implementing preventive and predictive measures is vital.	• IoT • ML • Cloud Service • Edge Computing	Diabetes, a major global cause of death, requires proactive prediction and prevention. HealthEdge, a smart health framework, uses IoT, cloud, edge processing, and machine learning to predict type 2 diabetes. Experiments demonstrate a 6% higher accuracy of the Random Forest (RF) algorithm compared to Logistic Regression (LR) for diabetes prediction. This framework anticipates type 2 diabetes through machine learning, assessing risk factors with sensors. The machine learning model is cloud-trained and deployed on edge servers for diabetes prediction, evaluated using real data and common machine learning algorithms.
HEALTH [76]	The challenge is to find solutions for complex issues in IoT-based medical services, affecting real-time medical data collection due to security, privacy, interoperability, scalability, and data integrity problems.	• IoT • Blockchain	The study explores blockchain and IoT integration for improved healthcare applications, including remote patient monitoring and medical record management. It aims to enhance understanding and identify challenges in healthcare enhancement.
HEALTH [76]	The challenge is to find solutions for complex issues in IoT-based medical services, affecting real-time medical data collection due to security, privacy, interoperability, scalability, and data integrity problems.	• IoT • Blockchain	The study explores blockchain and IoT integration for improved healthcare applications, including remote patient monitoring and medical record management. It aims to enhance understanding and identify challenges in healthcare enhancement.
HEALTH [77]	How portable health monitoring systems leveraging IoT operate	• IoT • GSM • Wi-Fi	The article leads to the development of a portable and efficient health monitoring system, combining user-friendliness with automated data management based on IoT. The presented

	remotely.		solution stands out for its simplicity and autonomy, enabling secure storage of patient data on local or external servers. The integration of components such as sensors, a GSM module, a microcontroller, Wi-Fi, and Bluetooth creates a compact and lightweight system, providing an innovative solution for remote health monitoring.
TRANSP [78]	Developing an innovative solution to enhance crime prevention through smart video surveillance in public transportation.	• Fog Computing	they presented a Fog-FISVER framework to improve crime prevention in public transport using intelligent video surveillance and fog computing. The prototype offers outstanding system performance and the survivability of the device, enabling rapid detection of crime with cost-effectiveness.
TRANSP [79]	The challenge is creating a smart city mobility platform that integrates IoT, IoE, Big Data, machine learning, and data analytics.	• IoT • Big Data • ML • Data Analysis • Internet of Everything (IoE)	The Sii-Mobility project creates a flexible platform for smart city mobility, integrating IoT/IoE sensors, Big Data, machine learning, and data analytics. Researchers demonstrate a system for dynamic traffic direction changes ensuring safety. A case study confirms flexibility and dynamic security configurations at various levels, including local, cloud-based, or a combination.
TRANSP [80]	The challenge is managing IoT-generated data in Intelligent Transportation Systems (ITS). The sheer data volume causes problems, with cloud-based analysis introducing latency, and fog computing having computing limitations. The goal is to design an effective hybrid IoT model for ITS that overcomes these challenges and meets complex system needs.	• IoT • Cloud Analysis • Fog Computing	IoT enhances Intelligent Transportation Systems ITS but generates data issues. Cloud analysis has drawbacks, leading to fog computing. Fog computing has computing limitations. A hybrid IoT model is proposed for ITS, effectively overcoming limitations.
TRANSP [81]	The challenge is efficient energy management for autonomous vehicles in smart networks. Current centralized approaches are inadequate for smart city energy management, and real-time energy transactions for IoT are crucial.	• IoT • Blockchain	To tackle these challenges, the BEST system was created to establish a secure energy exchange. It employs blockchain technology to decentralize request validation, ensuring resilience against failures. Additionally, a software-defined network is in place to ensure low latency and real-time services, thus bolstering overall system security.
TRANSP [82]	The challenge is creating an architecture for an IoT-based Intelligent Transportation System that utilizes big data analysis for real-time processing with Big Data techniques.	• IoT • Big Data	They introduced an IoT-based Intelligent Transportation System using Big Data techniques for real-time processing. This structure improves communication for users, split into three stages: data organization, real-time processing, and service management. It provides a flexible answer for intelligent transport planning through real-time big data processing, verified for efficient data management.

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TRANSP [83]	The challenge is security in the context of the (IoV) within (ITS). IoV offers advantages but generates a significant amount of real-time critical data, raising security concerns.	• IoV • RFID	The article addresses IoV security, current solutions, and performance issues. The authors propose a lightweight RFID-based authentication protocol to enhance security and network performance.
TRANSP [84]	The challenge lies in the complexity of managing public transportation systems (PTS) in metropolitan areas.	• IoT • Emerging Intelligent Techniques (EIT), • Cloud	The authors propose an IoT-based solution for improved public transportation management in metropolitan areas, emphasizing connectivity, cloud-stored data for tailored services, emerging intelligent techniques (EIT), and cloud-based software-defined networks. The main challenge is optimizing metropolitan public transportation through IoT.
TRANSP [85]	The challenge is focused on enhancing Intelligent Transportation Systems (ITS).	• IoT • Blockchain • Fog Computing	Researchers propose a secure fog computing network with blockchain to address user and IoT device authentication and reduce latency in ITS. Innovative algorithms, including an aggregated signature scheme, lead to a significant latency reduction, promising benefits for the ITS field.
TRANSP [86]	The challenge is ensuring security and privacy for smart vehicle users in the context of the Mobile Internet of Things (IoT). Rapid adoption of IoT devices in vehicles poses potential privacy risks from attackers.	• IoT	The authors solved the challenge with an innovative query scheme for smart vehicle data privacy and efficient service requests while preserving user information security. Network coding for complex queries avoids exposing service provider data, ensuring accuracy and enhancing privacy and service quality for smart vehicle users.
TRANSP [87]	The challenge is securing IoT-based urban transportation systems due to their complexity and diversity, which pose cyber-physical security concerns. The integration of 5G networks into public infrastructure connected to transportation systems via IoT also raises geospatial security issues.	• IoT • 5G	The authors introduce a geospatial modeling approach to develop a Smart Transportation Security System (STSS) addressing these issues. Their modeling and simulations, conducted in Beijing, China, aim to provide strategic security management guidelines for smart urban transportation.
TRANSP [88]	The challenge is the impact of integrating cloud, fog computing, and edge computing on modern transportation systems in smart cities and open data initiatives, where open data is vital for real-time information to both public and private transport users.	• IoT • ML • Cloud • Fog Computing • Edge Computing	The authors used machine learning and optimization to extract insights from data, aiding informed mobility choices. The article stresses the necessity of agile algorithms for real-time, large-scale transportation challenges, relying on IoT and open data, with parallelized optimization of biased-randomized algorithms to improve rapid heuristic performance.
TRANSP [89]	The challenge is the adoption of (ITS), hindered by operational issues like scalability and data security, despite the rapid rise of networking technologies, particularly	• IoV • Federated Learning (FL)	The authors explored using Federated Learning, an AI and machine learning technique, to tackle these challenges, showcasing its ability to bolster system resilience and reduce recovery times. This approach is considered vital for ITS.

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	the (IoV).		
TRANSP [90]	The challenge is implementing an IoT-based facial mask detection system for public transportation, especially buses. The authors employ facial recognition with advanced techniques like deep learning and image processing for real-time mask detection in a video stream.	• IoT • DL • ML	The authors introduced an IoT-based facial mask detection system for public transportation, focusing on buses. This system employs facial recognition and advanced techniques like (DL), (ML), and image processing to achieve real-time facial mask detection in video streams. Evaluations showed that the CNN classifier outperformed the DNN classifier, with an error rate as low as 1.1%. This enhanced model efficiently detects faces and masks while accommodating IoT resource constraints.
TRANSP [91]	The challenge is enhancing passenger mobility in urban transportation, particularly in developing countries.	• GPS	The authors introduced a smart system for urban passenger mobility improvement, offering real-time bus arrival information via widely available smartphones. The system uses GPS data from public transport drivers and has proven practicality in developing cities. It also includes an affordable electronic device for monitoring seat availability on buses, enabling passenger counting.
TRANSP [92]	The challenge is security and privacy complexity in IoT networks, especially for IoT-connected vehicles, which requires high data availability while defending against cyber threats.	• IoT • V2V (Vehicle-to-Vehicle) • V2I (Vehicle-to-Infrastructure)	The author presented a new cryptographic routing mechanism for secure V2V and V2I communications in smart vehicle networks. It employs attribute and identity-based encryption to enhance security while minimizing computational costs. Authentication, message integrity, and privacy are ensured through a hybrid cryptography system called AIBS (Attribute-Identity Based Signature), combining ABS and IBS. Simulations with potential attackers demonstrated remarkable efficiency in throughput, packet delivery, communication latency, and costs.
TRANSP [93]	The challenge is to improve real-time data security in Internet of Vehicles (IoV) communication within Autonomous Vehicle Systems (AVS), addressing issues related to communication interruptions and data privacy.	• IoV • Autonomous Vehicle Systems (AVS)	The authors aimed to improve data security with a trust-based privacy approach using encryption and steganography. They employed the Efficient and Secure Transmission (EAST) algorithm, known for its processing efficiency, to enhance data security in the context of IoV. The central concern is ensuring data confidentiality and preventing communication interruptions in AVS via IoV.
TRANSP [94]	The challenge is meeting increasing demand for efficient logistics in manufacturing, driven by the internet's rise, and Industry 5.0's reliance on the Industrial Internet of Things (IIoT) to serve customer needs in manufacturing and logistics.	• IoT	The authors introduced an IIoT model for logistics management, optimizing logistics, customer experience, satisfaction, and reducing transport costs. They improved operational efficiency through optimal route identification, real-time vehicle parameter monitoring, and preventive maintenance. Results showed increased customer satisfaction, cost reduction, improved energy efficiency, and model performance, rising from 77% to 98% through IIoT.

TRANSP [95]	The challenge is the high incidence of road accidents in Saudi Arabia, resulting in human casualties, injuries, and substantial financial expenses. Early accident detection is crucial, but delays can occur. Ensuring the security of sensitive data and privacy protection is a major concern when using (IoT) devices.	• IoT • GSM	In Saudi Arabia, road accidents are a pressing concern due to their human and financial toll. Early detection is vital, but delays happen. Ensuring data security and privacy, especially with IoT devices, is paramount. The authors developed a secure IoT system for instant accident detection, prioritizing driver safety and privacy through elliptic curve encryption over GSM. Results show adaptability for various IoT security and data protection needs.
TRANSP [96]	The challenge revolves around security concerns within the IoT and connected vehicle domains, particularly in the realm of connected autonomous vehicles (CAV). Security is paramount to ensure safe driving, but connected vehicles are susceptible to various cyber threats, such as Distributed Denial of Service (DDoS) attacks and single point of failure attacks, posing risks to system security and privacy.	• IoV • Blockchain	To enhance security and privacy in autonomous connected vehicles, the authors created a blockchain-based communication system. This system secures communications while safeguarding the privacy of vehicles and their occupants. Tests confirm its effectiveness against DDoS attacks.
TRANSP [97]	The challenge is efficient emergency management in intelligent transportation systems, especially facilitating the quick movement of emergency vehicles (EVs) during incidents. Urban traffic congestion causes severe delays, and current methods like modifying traffic lights may not consider potential disruptions to other vehicles or real-time adjustments.	• Unmanned Aerial Vehicles (UAV) • Emergency Vehicle (EV)	The authors introduced a priority-based incident management system for Unmanned Aerial Vehicles (UAVs) to improve Emergency Vehicle (EV) response times. This model considers potential disruptions, adjusts traffic lights to minimize disturbances, and ensures swift EV arrival at the incident scene. Simulations show an 8% reduction in EV response time and a 12% improvement in the time required to clear the incident area.
TRANSP [98]	The challenge is to monitor node activities in a smart transport network with cloud assistance, utilizing a collaborative hunting game model.	• IoT Vehicle • Cloud	The goal is to identify conditions promoting node cooperation. Researchers proposed an incentive-based system based on node roles and engagement, tested in a vehicle cloud for intelligent transport services. The results demonstrate that promoting adherence to network protocols and providing loyal service emerges as the optimal and consistent approach for nodes, leading to enhanced performance compared to alternative strategies.

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TRANSP [99]	The challenge is improving AI-driven autonomous decision-making in intelligent transportation systems (ITS) while protecting sensitive data from cyber threats.	• Federated Learning (FL) • Blockchain	The authors employed Federated Learning (FL) with blockchain to secure data integrity and detect cyber threats in connected vehicles (VANET) and intelligent transportation systems. Experimental results demonstrated an average 7.1% decrease in precision and accuracy while maintaining comparable recall.
TRANSP [100]	The challenge is efficiently managing low-latency IoT applications, optimizing edge computing resource utilization, and addressing the suitability of the cloud for latency-sensitive applications.	• IoT • Fog Computing • Cloud	The strategy improves IoT edge system reliability by reducing latency and energy consumption in resource allocation, with a 10.3% latency reduction and 21.85% lower energy use in simulations compared to prior methods.
SMART HOME [101]	The challenge is integrating lightweight, low-power IoT devices with blockchain technology effectively.	• IoT • Blockchain	Researchers created a blockchain model based on hypergraphs to reduce storage consumption and enhance security. By organizing storage nodes using the hyperedge, data storage is optimized. The model's design, security strategy, and practical applications were explored, particularly in smart home networks. Its storage performance was assessed through simulation experiments and network evaluations.
SMART HOME [102]	The challenge is enabling a person with disabilities to manage and monitor daily home appliances within a smart home system.	• IoT	Researchers have created an eye-tracking system designed to facilitate smart home control for individuals with disabilities while also allowing real-time monitoring through the Internet of Things. The system was tested with 29 participants, including a disabled user, over a seven-day period to evaluate its effectiveness and usability.
SMART HOME [103]	This article discusses the deployment of a smart home system based on the (IoT).	• IoT • ZigBee Communication Protocol • Cloud Server	The authors introduced a smart home system based on the Internet of Things (IoT), comprising a mobile app and a virtualized cloud server. It utilizes ZigBee wireless communication, a message telemetry queue, and Raspberry Pi for data collection. The system seamlessly integrates hardware and software, enabling efficient data analysis and user-friendly management.
SMART HOME [104]	The article focuses on the advancement of an (IoT) system for elderly individuals, including those with partial memory impairment such as Mild Cognitive Impairment (MCI) and dementia.	• IoT	They created an IoT system for elderly and memory-impaired individuals, enhancing safety with early alerts and discreet activity monitoring through ambient sensors. Data is sent to caregivers, and there's an emergency bracelet. This cost-effective, energy-efficient solution significantly improves the quality of life and safety for this demographic.
SMART HOME [105]	The problem is about creating wearable altimeter sensors based on the s (IoT) for the elderly.	• IoT • ML	Researchers developed wearable altimeter sensors using IoT for elderly individuals to prevent falls by identifying potential incidents. They suggested using temporal inference models, CM-I and CM-II, to identify instances of falls. Analysis of real and synthetic data showed promising results, suggesting these models could be integrated into healthcare for early fall monitoring in smart homes, aiding clinicians in incident anticipation via wearable IoT devices.

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SMART HOME [106]	The core issue is implementing an energy management system in smart homes, with a future-oriented emphasis on enhancing eco-friendliness, curbing energy waste, addressing health concerns, and mitigating cybersecurity risks.	• EMS (Energy Management System)	The authors introduced a smart home energy management system, highlighting the need for eco-friendliness, health, and cybersecurity in future research. However, the study identified shortcomings in security, privacy, scalability, and interoperability. Managing resident comfort also proved challenging, potentially impacting health.
SMART HOME [107]	The issue is about introducing a fuzzy framework for (IoT) based Smart Home Monitoring Systems (FF-SHMS) to save energy by monitoring demand, conserving green energy, and utilizing microgrids.	• IoT	The author introduced a fuzzy structure for IoT-based Smart Home Monitoring Systems (FF-SHMS) to save energy by optimizing smart microgrids, incorporating renewable energy sources, and enhancing electricity efficiency. This framework considers sustainability, load regulation, and various parameters, resulting in effective microgrid energy management for both controlled and uncontrolled energy efficiency.
SMART HOME [108]	The core issue is the security and privacy of smart home users, as accessing these systems through public channels exposes them to the risk of hacking and information compromise, despite the overall benefits for quality of life.	• SGX Technology (Software Guard Extensions)	The authors introduced a specialized AKA scheme for smart homes, utilizing a gateway for connectivity and integrating SGX technology for security. Cost analysis indicates its efficiency. Future recommendations include diverse authentication methods like biometrics, multi-factor authentication, and strengthening data security with robust passwords and restricted smart device access.
SMART CITY [109]	The central problem lies in the substantial urban challenges stemming from the global shift from rural to urban areas, impacting education, health, traffic, energy, waste management, unemployment, and crime control.	• IoT	The author emphasizes ICT's vital role in transforming traditional cities into smart cities and explores the relationship between IoT and smart city features. They describe a future scenario using IoT to make waste management better in smart cities.
SMART CITY [110]	The problem is about creating smart cities, with Fog Computing and the (IoT) playing a vital role in this process.	• IoT • Fog Computing	The article discusses the advantages of Fog Computing and proposes an IoT-based architecture to tackle network scalability and data processing challenges when developing smart cities.
SMART CITY [111]	The problem is about enhancing smart cities by leveraging IoT-based applications using cloud technology.	• IoT • Cloud	The author discusses how IoT and the cloud enhance urban living in smart cities, focusing on real-world applications that improve well-being and resource management while highlighting potential for future research in new applications.
SMART CITY [112]	The problem is about enhancing waste management methods in the context of smart cities using the (IoT).	• IoT • IoV	The researchers addressed IoT sensor energy efficiency issues in waste management. They introduced a new data collection method using the Internet of Vehicles (IoV) to enhance smart city waste management efficiency. They also presented an eco-energy model with ant-inspired routing algorithms for low-power wireless

			sensor networks and analytical methods for assessing energy consumption.
SMART CITY [113]	The issue is the need for lightweight ontological models in IoT environments, especially in sustainable smart cities, to facilitate real-time data annotation due to the increasing use of sensors and IoT technologies.	• IoT • IoT-Stream model	The rise of sensors and IoT technology requires lightweight ontological models like IoT-Stream for real-time data annotation. To enhance IoT-Stream, the authors introduced a sensor taxonomy for better mapping in smart cities, reducing redundancy and promoting seamless information exchange.

4. FINDINGS AND DISCUSSIONS

Based on the findings of a research study, Figure 4 (attached herewith) and Table 3 present a detailed breakdown of various application domains within the Internet of Things (IoT). The analysis of articles published between 2018 and 2023 emphasizes the significance attributed to the agriculture, health, and transportation sectors, which emerge as the most frequently addressed topics in specialized literature. Notably, there is a comprehensive exploration of industrial agriculture, identified not only as the most studied domain but also characterized by exceptional reliability in practical applications.

Table3: Distribution of Articles and the Rate of IoT Usage by Application Sector (2018-2023).

Sectors	Number of articles	The rate of usage of IoT in these domains
Agriculture	43	30%
Healthcare	26	26%
Transportation	23	21%
Smart City	5	10%
Smart Home	8	13%

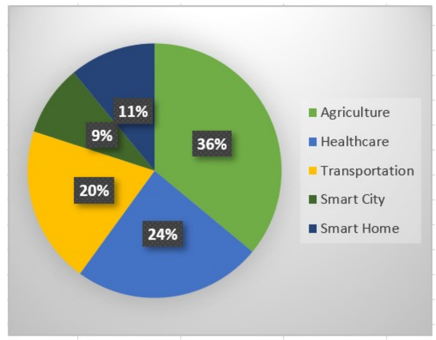

Figure4:The Rate of IoT Utilization in These Domains.

The Transportation Sector

In the context of applying IoT to the transportation sector between 2018 and 2023, various technologies play a crucial role, as illustrated in Figure 5 and detailed in Table 4 below. This table presents the percentage of usage for these technologies, including IoT, AI, Fog Computing, blockchain, Edge Computing, deep learning, machine learning, Internet of Vehicles (IoV), and Unmanned Aerial Vehicles (UAVs). The analysis of research in the transportation sector during the period from 2018 to 2023 reveals that the most utilized and focused technologies are IoT and AI. These technological advancements significantly contribute to the modernization and optimization of transportation systems, enhancing efficiency, safety, and sustainability of operations. This period has been characterized by a growing integration of IoT and AI, demonstrating their relevance and positive impact in the transportation industry.

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Table 4: The Rate Of Technology Adoption In The Transportation Sector From 2018 To 2023.

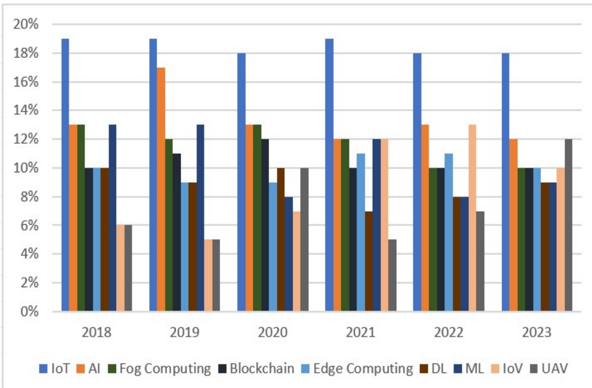

Figure 5: The Technologies Most Extensively Utilized In The Transportation Sector In Recent Years.

4.1 The Smart Homes

From 2018 to 2023, the integration of IoT into smart homes has been characterized by a pivotal role played by various technologies, as depicted in Figure 6 and detailed in Table 5. This breakdown not only highlights the usage percentages of key technologies such as IoT, AI, Blockchain, ML, and cloud computing but also explores their evolving trends and impacts. Research analysis emphasizes that IoT and AI have emerged as prevalent technologies, contributing significantly to the progression and refinement of smart home systems. This era has witnessed notable advancements, enhancing operational efficiency, security features, and sustainability in smart home functionalities. The assimilation of these technologies creates sophisticated homes with automated, personalized, secure, and scalable features. The interplay between IoT and AI has led to the development of smarter, more intuitive home environments. However, it is crucial to address security and privacy factors throughout their lifecycle. As IoT and AI continue to shape the future of smart homes, a vigilant approach towards robust security measures and user privacy becomes increasingly critical. This involves the mitigation of potential vulnerabilities and the implementation of safeguards to protect users' data and personal information.

Table 5: The rate of technology adoption within the smart homes sector between 2018 and 2023.

The technologies in Transportation	2018	2019	2020	2021	2022	2023
IoT	19%	19%	18%	19%	18%	18%
AI	13%	17%	13%	12%	13%	12%
Fog Computing	13%	12%	13%	12%	10%	10%
Blockchain	10%	11%	12%	10%	10%	10%
Edge Computing	10%	9%	9%	11%	11%	10%
DL	10%	9%	10%	7%	8%	9%
ML	13%	13%	8%	12%	8%	9%
IoV	6%	5%	7%	12%	13%	10%
UAV	6%	5%	10%	5%	7%	12%

The technologies in Smart Homes	2018	2019	2020	2021	2022	2023
IoT	26%	26%	26%	25%	28%	25%
AI	22%	20%	20%	20%	20%	21%
Blockchain	19%	19%	18%	18%	18%	17%
Cloud Computing	17%	18%	17%	18%	18%	18%
ML	16%	17%	19%	19%	16%	19%

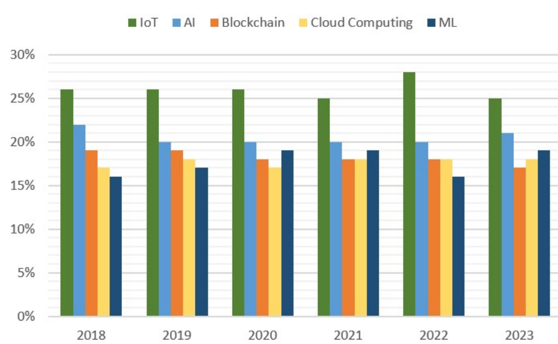

Figure 6: The technologies most widely employed in the smart homes sector in recent years.

4.2 The Smart City

In the context of applying IoT to Smart Cities from 2018 to 2023, various technologies play a crucial role, as illustrated in Figure 7 and detailed in Table 6 below. These tables provide a breakdown of the usage percentages of key technologies, including IoT, AI, Fog Computing, Cloud Computing, and the Internet of Vehicles (IoV). Research analysis within the Smart City sector highlights IoT and AI as the most widely used and focused technologies. The integration of these technologies in Smart Cities aims to enhance operational efficiency, sustainability, citizens' quality of life, and urban resource management. However, it is crucial to consider aspects of security, privacy protection, and interoperability when implementing these technologies on an urban scale. This period has witnessed a significant evolution in the adoption of these technologies, with an increased focus on optimizing urban infrastructures and improving the quality of urban life.

Table 6: The rate of technology adoption in the smart cities sector between 2018 and 2023.

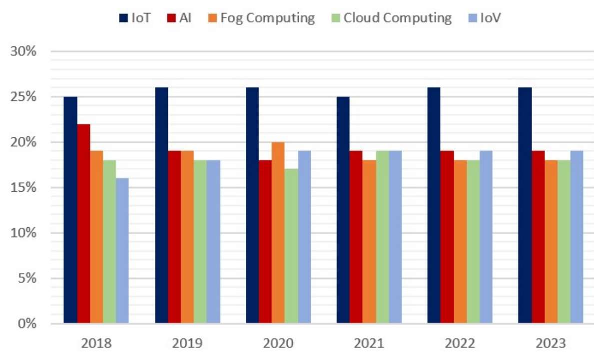

Figure 7: The technologies most extensively utilized in the smart cities sector in recent years.

4.3 The HealthCare

In the field of healthcare, IoT, AI, Blockchain, Cloud Computing, Fog Computing, Edge Computing, ML, and ECG play a crucial role, as detailed in Figure 8 and Table 7. Applied from 2018 to 2023, these technologies modernize healthcare systems by enhancing operational efficiency, security, and sustainability. Their integration promotes improved diagnostics, secure and accessible information management, and an overall enhancement of patient care. These advancements significantly contribute to the digital evolution of the healthcare sector, with an increasing focus on digitizing medical processes, implementing advanced AI-based algorithms, and further integrating IoT into medical practices. These progressions aim to enhance operational efficiency, strengthen diagnostic accuracy, proactively manage patients, and promote a more personalized approach to healthcare, underscoring the crucial importance of this period in the technological evolution of the healthcare sector.

Table 7: The rate of technology adoption in the healthcare sector between 2018 and 2023.

The technologies in HealthCare	2018	2019	2020	2021	2022	2023
IoT	19%	19%	20%	22%	20%	19%
AI	18%	17%	19%	21%	18%	17%
Cloud Computing	12%	12%	10%	10%	9%	8%
Fog Computing	11%	11%	15%	9%	9%	8%
Edge Computing	11%	10%	10%	9%	9%	12%
Blockchain	12%	11%	10%	9%	15%	12%
ML	12%	14%	9%	15%	15%	13%
ECG	5%	6%	7%	5%	5%	11%

The technologies in Smart Cities	2018	2019	2020	2021	2022	2023
IoT	25%	26%	26%	25%	26%	26%
AI	22%	19%	18%	19%	19%	19%
Fog Computing	19%	19%	20%	18%	18%	18%
Cloud Computing	18%	18%	17%	19%	18%	18%
IoV	16%	18%	19%	19%	19%	19%

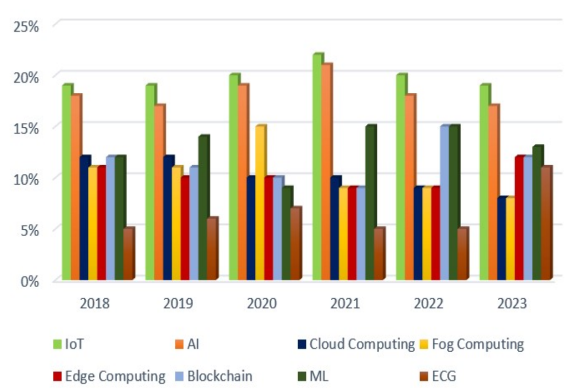

Figure 8: The most widely used technologies in HealthCare in recent years.

4.4 The Agriculture and Aquaculture

In the realm of applying IoT in agriculture and aquaculture, a range of technologies plays a pivotal role, as illustrated in Figure 9 and detailed in Table 8 below. These tables provide a breakdown of the utilization percentages of key technologies, including IoT, AI, Blockchain, Cloud computing, WSN, DL, ML, and UAV. Research analysis within the agriculture and aquaculture sector indicates that IoT and AI stand out as the most widely used and

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concentrated technologies. This array significantly contributes to the modernization and optimization of agricultural systems, leading to improved efficiency, safety, and operational sustainability. The integration of these technologies fosters the emergence of precision agriculture and intelligent aquaculture, enabling more efficient resource utilization, informed decision-making, and sustainable food production. However, considerations related to data privacy, security, and technological accessibility must also be considered during their deployment. In the period from 2018 to 2023, these technologies experience increasing adoption, with a particular emphasis on the development of more advanced solutions to address the specific challenges of agriculture and aquaculture. The heightened use of IoT and AI results in significant advancements in intelligent crop management, real-time monitoring, and the promotion of sustainable agricultural practices, illustrating a crucial period of innovation and technological evolution.

Table 8: The rates of technology adoption in the agricultural and aquacultural sectors between 2018 and 2023.

The technologies in agriculture and aquaculture	2018	2019	2020	2021	2022	2023
IoT	23%	21%	20%	22%	20%	20%
AI	20%	18%	19%	19%	18%	17%
Blockchain	15%	18%	12%	15%	13%	12%
Cloud Computing	7%	13%	10%	10%	10%	10%
WSN	5%	10%	8%	5%	10%	10%
DL	13%	10%	11%	10%	10%	10%
ML	12%	10%	10%	10%	10%	10%
UAV	5%	10%	10%	9%	9%	11%

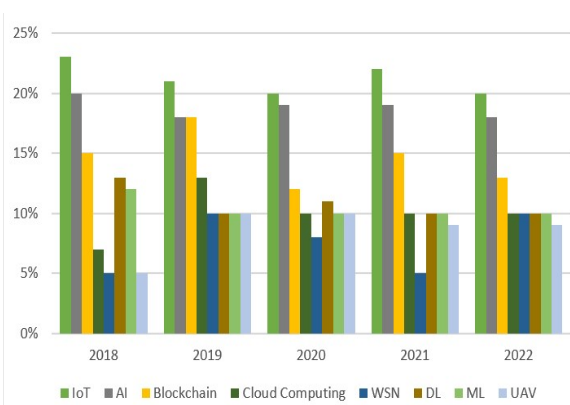

Figure 9: The most widely used technologies in agriculture and aquaculture in recent years.

In summary, based on the analysis of articles published from 2018 to 2023, the Figures and Tables above highlight a diverse range of predominant technologies in various fields, including agriculture, health, transportation, smart cities, and smart homes. These technologies encompass IoT, AI, blockchain, Wireless Sensor Networks (WSN), ML, DL, Cloud computing, Edge computing, Fog computing, UAV, IoV, and many more. Notably, researchers have primarily focused on improving data collection methods during this period, with a particular emphasis on technologies like IoT and AI specifically applied in these sectors. Deployed across diverse sectors including agriculture, health, transportation, smart cities, and smart homes, these advancements have optimized agricultural resource management, enhanced medical diagnostics, strengthened transportation efficiency, and contributed to the development of smart cities and homes. However, concerns persist regarding data security, privacy protection, and equitable access to these innovations. This period represents a crucial stage in the adoption and evolution of these technologies, while also posing ethical, regulatory, and socio-economic challenges. The implementation of these methodologies, especially in the agricultural sector, particularly in aquaculture (fish farming), brings about various advantages, distinctive features, as well as positive and negative aspects.

4.4.1 Key Benefits of Using IoT and AI in Fish Farming

In the current context marked by a constantly increasing global food demand, fish farming becomes an essential pillar of the agricultural industry. This growth in food demand creates an urgent need to optimize aquaculture production. It is in this context that emerging technologies, such as the IoT and AI, play a crucial role in bringing about a significant transformation. These innovative advancements offer a multitude of substantial benefits, providing notable opportunities to enhance the efficiency, sustainability, and profitability of fish farming. Within this article, we have explored these advantages, highlighting how IoT and AI are revolutionizing the aquaculture sector. This transformation is materialized through real-time monitoring, intelligent automation, proactive fish health management, anticipation of feeding needs, and reduction of operational costs, as illustrated in Figure 10 below. These technological advancements create opportunities for fish farming characterized by increased efficiency, sustainability, and reliance on data, contributing to the resolution of challenges linked to global food supply.

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Real-time monitoring of environmental parameters	IoT sensors facilitate continuous monitoring of environmental factors like water quality, temperature, pH, and salinity in real-time, ensuring the maintenance of ideal conditions for fostering fish growth.
Process automation	AI can be used to automate tasks such as fish feeding, aeration, and filtration system control, thereby reducing the reliance on manual labor.
Forecasting feeding needs	AI can analyze data to predict the feeding needs of fish based on their growth, thus optimizing food management.
Improvement of fish health	IoT devices can monitor fish health, detecting early signs of diseases and enabling prompt intervention.
Cost reduction	Automation and process optimization can reduce operational costs and increase the profitability of fish farming.

Figure 10: Key Benefits of Using IoT and AI in Fish Farming.

4.4.2 Specific Aspects of Fish Farming

Fish farming exhibits unique features, as depicted in Figure 11 below. These specific attributes create opportunities for enhancement that can be achieved by integrating IoT and AI. By leveraging these technologies, the aquaculture industry can improve its efficiency, profitability, and sustainability. These advancements facilitate more precise management, enhance prevention of fish health issues, and optimize resource utilization, thereby contributing to the growth of the aquaculture sector.

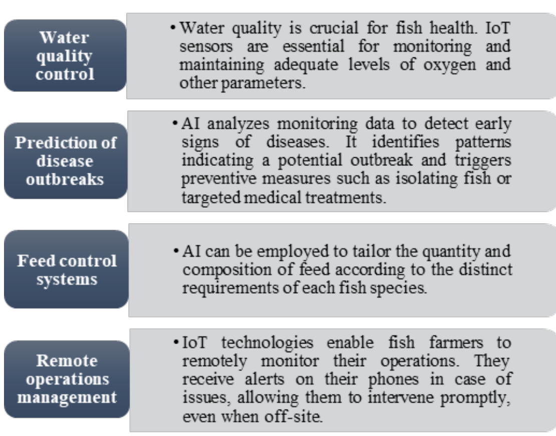

Figure 11: Specific Aspects of Fish Farming with IoT and AI.

4.4.3 Advantages and Disadvantages of Using IoT and AI in Fish Farming

The advantages of incorporating IoT and AI in aquaculture have garnered significant attention, introducing fresh possibilities and prompting essential questions. The use of these technologies, as depicted in Figures 12 and 13 below, offers distinct benefits, particularly in enhancing production efficiency, fish health, and environmental management. Nevertheless, it also presents challenges such as concerns about data security, the requirement for technical expertise, implementation costs, and ethical considerations. From this standpoint, it is essential to carefully analyze both the positive results and challenges that arise from integrating IoT and AI in the aquaculture industry.

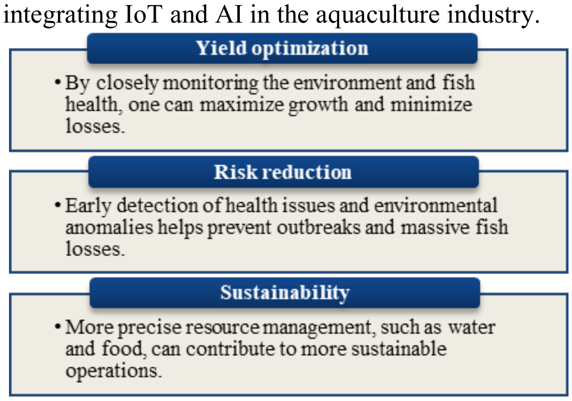

Figure 12: Benefits of using IoT and AI in fish farming.

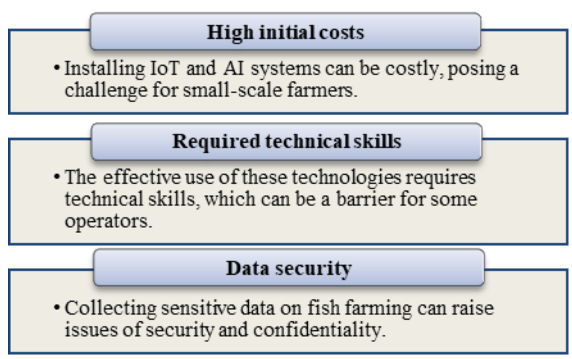

Figure 13: Disadvantages of using IoT and AI in fish farming.

Our comparative study with other works highlights a significant gap in understanding the specific implications of integrating IoT and AI in various fields such as healthcare, transportation, smart cities, smart homes, and more specifically, in agriculture, with a particular focus on aquaculture. While previous research has focused on productivity gains, our study distinctively explores how these technologies can contribute to reducing the environmental footprint of agriculture, particularly in

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fish farming. As depicted in Table 9 below, we have emphasized the monitoring of water quality parameters such as pH, temperature, and dissolved oxygen concentration (DO) using an integrated IoT system. This approach aims to preserve aquatic life by maintaining a connection with fish health and detecting signs of fish diseases through AI algorithms. Going beyond a mere research update, our contribution provides a unique perspective on the integration of IoT and AI in aquaculture, emphasizing environmental sustainability and harmonious coexistence with local biodiversity. Through a detailed analysis of these mechanisms, our study endeavors to bridge the existing gap in understanding and maximize the positive impact of these technologies in the agricultural sector, particularly in the field of aquaculture.

Table 9: Comparison of our study with others in the literature.

Ref	IoT	AI	AI-aided -IoT	Aquaculture		
				Water Quality	Parameter water	Fish Health
[28]	✓	✓	✓	✓	• pH • Temperature • Water level • Ammonia • Electrical conductivity	×
[31]	✓	✓	✓	✓	—	×
[34]	×	✓	×	✓	Temperature	×
[35]	×	✓	×	×	×	✓
[39]	×	✓	×	×	×	✓
[43]	✓	✓	✓	×	×	✓
[46]	✓	×	×	✓	—	×
[47]	✓	✓	✓	✓	—	✓
[48]	✓	✓	✓	✓	—	✓
[50]	✓	✓	✓	✓	Dissolved oxygen (DO)	✓
This work	✓	✓	✓	✓	• pH • Temperature • Concentration of Dissolved Oxygen (DO) • Salinity	✓

The critical point of view presented in the article involves an extensive analysis of the integration of Artificial Intelligence (AI) and the Internet of Things (IoT) across diverse sectors, encompassing health, transportation, smart cities, smart homes, and agriculture, with a particular emphasis on aquaculture. Within the realm of aquaculture, potential threats to validity arise from factors like water quality, seasonal variations, and specific characteristics of raised aquatic species, significantly impacting studies that integrate IoT with AI. For instance, water quality directly affects the precision of IoT sensor measurements, introducing the risk of seasonal biases due to environmental variations. The distinct characteristics of raised aquatic species necessitate specific AI approaches tailored to meet their requirements. Critique criteria specific to aquaculture highlight the paramount importance of sensor relevance for monitoring water quality to ensure reliable data collection. Evaluating this relevance within the aquaculture context is crucial for maintaining data quality. Similarly, the validity of AI models for specific species is indispensable, requiring adaptation to the distinct characteristics of each species for precise results. However, the complexity of AI algorithms, including Deep Learning (DL) and Machine Learning (ML) models, may pose additional challenges. Integrating these considerations of validity threats and critique criteria specific to aquaculture enables a more in-depth analysis of the integration of IoT with AI in this sector.

Our study boasts several strong points, including a comprehensive examination of how IoT and AI impact various application sectors. The focused analysis of pivotal sectors like agriculture, healthcare, transportation, and smart homes vividly illustrates the tangible utility of IoT and AI, addressing specific challenges and enhancing overall quality of life. Moreover, the study provides up-to-date insights into technological advancements through the analysis of recent trends. The incorporation of case studies and successful implementation examples not only validates our findings but also serves as a valuable blueprint for future integrations of IoT and AI. However, the study has identified certain weaknesses. While covering multiple domains, it may lack specific technical details for each sector, potentially limiting its usefulness for specialists seeking in-depth information. Predictions about future trends may lack reliability due to the rapid pace of technological evolution and the influence of unpredictable external factors. Additionally, a notable absence of critical discussion on challenges related to the integration of IoT and AI, such as security, privacy, and ethics, could diminish the study's relevance. Furthermore, the study does not adequately address the need for advanced technological infrastructure, which poses a significant obstacle, particularly in developing countries.

5. CONCLUSION AND FUTURE WORK

The Internet of Things (IoT) finds applications in various sectors, including agriculture, healthcare, smart homes, smart cities, and transportation. It plays a crucial role in improving processes, increasing efficiency, facilitating informed decision-making, and enhancing life in these areas. Our study focuses on the impact of IoT in industrial agriculture, particularly in aquaculture, where it has significantly transformed traditional farming practices. This transformation is evident in increased production, cost reduction, strengthened environmental sustainability, and improved traceability of food products. The technological advancements brought about by IoT have revolutionized farm management, yielding tangible benefits in terms of efficiency and profitability. In this article, we concentrated on conducting a bibliometric analysis of IoT-related industrial sectors for the period 2018-2023. The analysis sheds light on the most commonly explored sectors, their popularity, performance, and the prevailing technologies, especially in areas such as operational optimization, efficiency improvement, cost reduction, and enhanced security.

The future of (IoT) in agriculture appears promising, particularly with its integration with artificial intelligence (AI). This amalgamation is expected to elevate precision, sustainability, and automation in intelligent farming, offering the potential to decrease labor costs while enhancing the quality and efficiency of food production. A forthcoming article will delve into the synergies of integrating IoT and AI technologies with existing data to monitor, control, and enhance water quality in aquaculture fish farms. The authors have achieved high-performance and efficient results with these technologies, showcasing the feasibility of refining real-time outcomes to address identified issues.

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