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Research Article

IoT for Development of Smart Dairy Farming

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Internet of things (IoT) and data-driven techniques are creating greater opportunities for smart dairy farming. The demand for milk is continuously increasing due to increasing population of the world. The consumption of the dairy products is more in developed countries as compared to developing countries. To meet this increased demand for milk products, better technological techniques for improving milk yield are required. It is expected that the use of IoT and different AI techniques can assist a farmer to overcome different traditional farming challenges and increase the milk production. In this research, the authors address different challenges that a dairy farmer has to face in daily life. Brief introduction of smart dairy farming (SDF) is presented with respect to the innovation in production and the processes of smart dairy farming. This review focuses on different aspects of smart dairy farming, and finally a state-of-the-art framework that can assist the farmers to increase the milk yield by using different latest technologies has been proposed. These technological methods can decrease the factors negatively affecting milk production and increase those positively affecting production with minimal resources.

1. Introduction

Smart dairy farming (SDF) is the key concept that can satisfy the increasing demand of quality dairy products. SDF can reduce the environmental issues, decrease the use of resources, and raise the animal health by using advanced sensing and data analyzing technologies. Since 2015, milk is the most demanding product and it has become the product with heavy price fluctuation [1]. In order to compete in the worldwide market, the European dairy market needs to improve its production by using Internet of things. Table 1 presents a comparative analysis of different countries for worldwide cow population and milk production.

Traditionally, there is a distinction between dairy cow and beef cow but often the same stock can be used for beef and dairy production. Cow produces a large amount of milk in its lifetime. Dairy cow can be found at farms or in herds where a farmer or herd manager takes care of the cow for producing milk. According to the reports, there are 264 M cows around the world and they produce around 600 M tonnes of milk per year [2]. Table 1 compares the top ranked countries for cow population in terms of milk production. The table contains three categories: developed, developing, and underdeveloped countries. According to these facts and figures, India is the most populated with cows and produces approximately two-thirds of the amount that the USA produces every year. Table 2 shows the reasons for low milk yield production and possible solutions from previous research studies.

1.1. Smart Dairy Farming. Dairy farmers are in the era of precision farming which is considered to be more important for information provision and for capturing

Table 1: Comparative analysis of different countries for worldwide cow population and milk production [2].

Category	Country	Worldwide dairy cow population (%)	Worldwide cow milk production (%)
Developed	USA	3.4	14.6
	Germany	1.6	4.9
	France	2.0	3.9
	New Zealand	1.8	2.8
Developing	China	4.7	6.0
	India	16.5	8.4
	Brazil	8.7	5.3
Underdeveloped	Pakistan	3.8	2.1
	Bangladesh	1.5	2.0

Table 2: Reasons for low milk yield and their possible solutions.

Category	Reasons	Reference	Solutions	Reference
Health	Body weight: Milk yield is directly affected by the weight of the animal. Different studies have shown that healthy animals can produce more milk. If increment of milk yield is a goal, then maintaining cow health and weight is a necessary job.	[1, 3, 4]	Individual information analysis and context interpretation	[5]
	Mastitis: In dairy cows, mastitis is caused by bacteria that invade the udder and multiply in the milk-producing tissues, lessening milk yield.	[3, 6, 7]	Automated milking claws that can detect udder diseases like mastitis	[5, 7]
	Calving interval: The abnormal time period between the birth of calves can be the reason of lower milk yield.	[1, 6–8]	Smart observation and placed historical data for recording the interval	[5, 7]
Food and water	Nutrition: The major sustenance that should be a part of dairy cows feed includes magnesium, calcium, phosphorus, sulfur, sodium, chlorine, and potassium.	[1, 3, 9]	Automation of data collection to measure nutrition	[5]
	Feeding: Animal feeding can be a complex task. Overcrowded feed bunk can reduce feed intake and this can cause lowered milk production.	[3, 9–11]	Robotic system that can feed automatically after observing the digested food	[10]
	Water supply: Dairy milk contains 87% of water, and shortage of adequate water intake can lessen the milk yield.	[11, 12]	Automated water supply after observing being thirsty	[5, 12]
Herd management system	Comfort level: Dairy cows with more cleanliness and less stress level can produce more nutritious milk. Overcrowding and slippery floor are the two major reasons for discomfort of dairy cows.	[13, 14, 15]	Behavioral indicators	[5, 16]
	Environment: Keeping dairy cows clean is a vital procedure to have better milk yield.	[17–19]	Better hygiene management	[5]

competitive market, hence the need for a variety of data sources that contain the dynamic and static cow data about feeding, calving, nutrition, insemination, and the process of milk production. Internet of things started influencing the milk production. This step should necessarily be taken to meet the demand for dairy for huge population of the world. These are almost the last decades when the milk demands are fulfilled without the help of the latest technology; after that it will not be possible to encounter the demands for dairy and dairy products without technology. It is always considered as a challenging task to decide the correct time for milking the cow. Lack of technology can cause the milk to be perishable and fragile. In this matter, IoT can support farmers with wearable sensor devices to keep them aware of the status of every cow. The sensor-based system can effectively and correctly detect the illness of the cow, before it effects the milk production. The farm owner can place the sensor onto the cow's neck, tail, or leg for acquiring real time data to examine numerous factors like cow's behavior, activity, health, feed consumption, milk production, and fertility management. These wearable sensors can spot cow's illness and diseases such as mastitis or any other disease that can reduce milk production [3].

1.2. Innovation in SDF. According to the dictionary of business, innovation is a practice for translating an invention into any service that creates a value and customer will pay for it. Innovation in smart dairy farming is related to innovation in production (milk yield) and process of dairy farming. Dairy farm owners are the forefront for the farming innovation. In an organization, a product is something that will be created by a business company and will be sold to another company or the customer. Dairy farmers produce milk in their farmers, which will be sold to other milk companies. In this innovation, different latest technologies can be used for increasing the milk yield. A process can be coherent activities to convert input to output. Process innovation can be different set of activities that can be done at different levels in a smart dairy farm. In a dairy farm, only milking process can be seen as singular process, but on the other hand there are many activities that are performed in the farm like feeding, cow monitoring, and preserving milk. Innovation can be in different procedures like the feed system that can sense the hunger need of the cow and automatically feed the cow and automatic heat detection that will assist in reproduction as shown in Figure 1. Assessing health and monitoring cows for disease detection and prevention will help the farmer to locate any animal that needs medical attention.

The smart dairy farming includes real time sensors that collect data from cows with the help of wearable smart collars, machine learning data analysis, and cloud-based data centers that manage data and support the farmer in order to manage quality of dairy products as depicted in Figure 2.

The use of hardware and package will increase the productivity of the farming trade to satisfy the challenges it faces by assembling completely different information points to boost the industry's production. This technology is additionally harmless to the atmosphere and to the cows; thus it appeals to several completely different folks and teams, in contrast to the genetically changed hormones and alternative harmful and unnatural additives that are usually added to extend productivity. Smart farming is not just monitoring; it is also related to proper business management. By gathering raw data like insemination moment, pregnancy, or calving time, this data is used for value information and for applying some probability and statistics to plan the future work and manage dairy farm properly. In the example of a cow, technology can inform a farmer about the day of estrus, insemination, and parturition and can also calculate the age at initial parturition and the parturition interval between ordered parities.

2. Background

Demand for dairy products is rising day by day due to increasing population of the world. According to previous reports, the consumption of dairy and dairy products is more in the developed countries as compared the underdeveloped countries, but this change is getting bigger after increasing of world population and change in diet. Almost 80% of dairy in underdeveloped countries is from small farmers [2]. These types of small farmers and family farmers are far from the technology and practice traditional farming. For capturing the increased demand of the world, the use of technology in this platform is still required.

In this modern business world, dairy farmers are facing many constraints like herd management, fixed production capacity, and farm labors that are very expensive. With these constraints and challenges, a dairy farmer can increase productivity and efficiency using enhanced reproduction method, smart monitoring of herd management for preventing diseases, detection of health issues, and smart milk production. Table 3 presents a comparative analysis of different researches on dairy farms.

2.1. Literature Review. Researchers introduced the main idea of SDF almost two decades ago, and the development of smart dairy farms has reached the market. Different researchers have different researches and contributions. In research [20], different ontologies have been combined for enabling data analysis in SDF. The authors have designated and implemented a smart dairy farming project with sensor-enabled technology. Different activities of cows have been monitored. In the results, the researchers have defined feed efficiency ontology as the feeding procedure which ultimately leads to better milk production. For increased milk productivity, SmartHerd management [21] for analyzing animal behavior and health monitoring has been prospered. In this research, micro service oriented design has been presented to assist distributed computing. This research also addresses some issues for implementing the IoT-based dairy farming like Internet connectivity in farm locations that are mostly at remote areas. For addressing this issue, the authors have proposed a fog-based architecture that reduces the transaction cost by 84%. Animal health and welfare constitute the major challenge for the dairy farmers. The review in [22] emphasizes the integration and combination of new emerging sensor-based technology with the activity-based system. This novel technology can assist farmers in observing cow behavior and breeding system.

The researchers and industries are aiming to improve the health of dairy animals for cultivating milk yield. In this exploration, different latest technologies have also been included for improving the reproduction of cows. In the research [23], the authors described different key areas for fertility management with the help of sensor devices. This review describes the current and future aspects for better reproduction. The authors also state that there is still a need to consider the genetic selection for breeding procedure and reproduction management (early detection of pregnancy). IoT is the perfect match for smart agriculture farming and dairy farming. In the research [24], the authors proposed an IoT-based semantic model for farming application. According to the authors, heat measurement in fertility management is the most complex task. For better fertility management a tool has been proposed. The automatic heat detection is a tool that can assist to manage fertility and reproduction methods. Maximum productivity instead of larger herd is the primary aim of the researchers to meet the increased demand of market. In research [25] the authors have employed a real time big data warehouse in dairy farms.

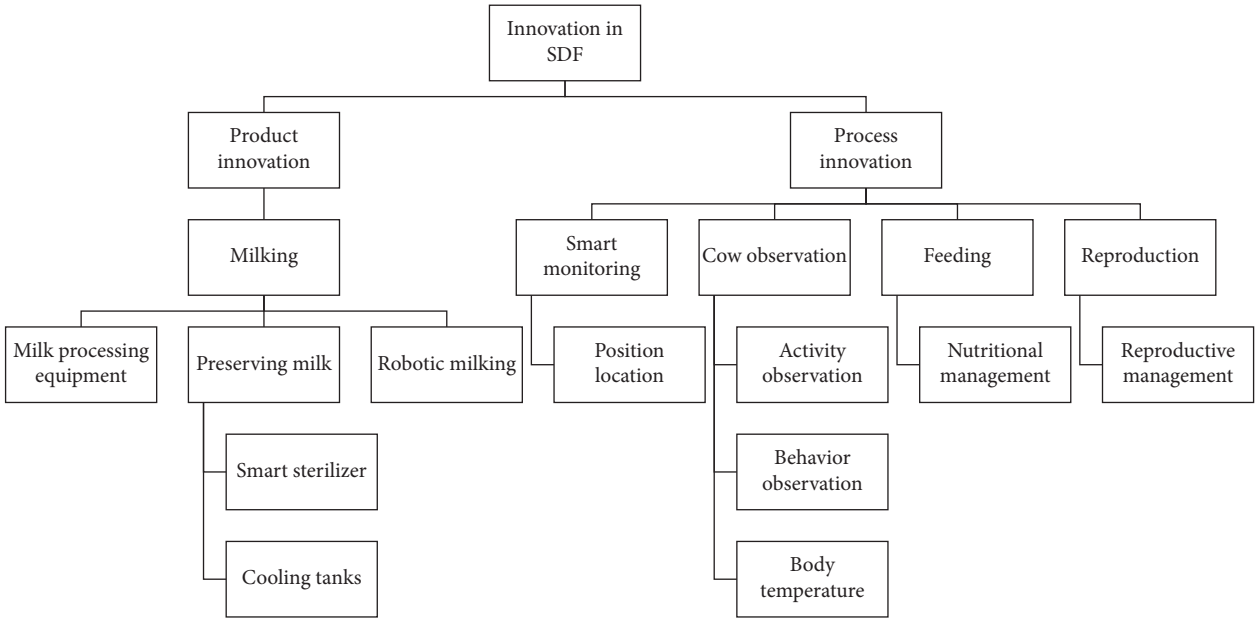

Figure 1: Innovation in smart dairy farming.

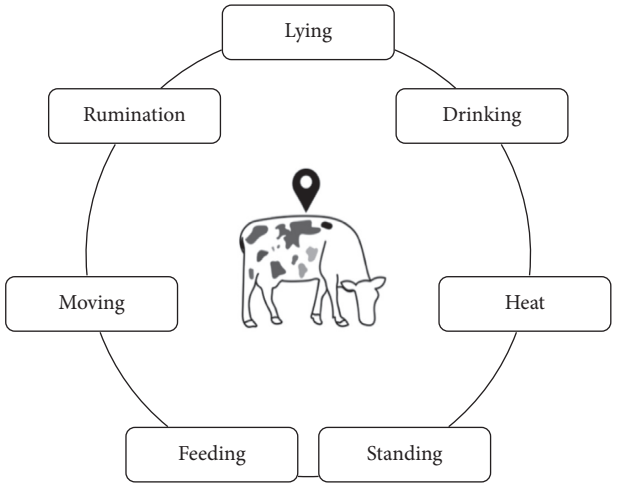

Figure 2: Sensors for SDF.

This research focuses on different aspects of smart dairy farming like milk productivity, mastitis detection, and feed efficiency. The authors provide a practical application with integration of big data streams. This research contributes to the development of centralized smart farming. Precision farming is one of the major solutions for meeting the worldwide dairy needs. For implementing precision farming, many challenges are faced like integration of heterogeneous entities. In research [26], the authors have proposed a novel concept of dairy framing ontologies. The authors created a project named agriOpenLink for integration of different heterogeneous entities in smart dairy farming. According to their research, dairy farming ontology is based on knowledge management that can further be enhanced with agriculture.

In this technological era, dairy business is also an attractive business for young people but the demands of the farmers can vary according to the location. In research [27], the authors described the different mentalities of people who are localized in different urban, peri-urban, and rural areas. According to the research, the farmers who are localized in urban areas have small farms with limited number of cows, and they are more concerned with cow production than peri-urban and rural areas. The authors focus on the feed of the cow, because effective feed can produce more milk. The concept of robotic milking is not new, but reducing the overall labor cost and procedural cost is the most challenging task in large-scale dairy farming. In research [28], the authors proposed a novel robotic milking technology that can grab the milking claws to cows. This system contains automated milking, cleaning, and feeding of cows. Robotic feeding is also a feature of this system; this system can calculate the effectiveness of feed for milk production and the nutritional requirement of a cow. Automated milking system can help to reduce labor cost. In research [29] the author describes a milking technique that can detect the disease related to udder like teat and mastitis. Researchers proposed a Haar cascade classifier for detection of teat. This classifier is an image-based processing technique which can detect different diseases in the udder of a cow. Various factors that can cause low pregnancy rates have been observed like the lack of nutritional requirements. In research [30, 31], the authors have described static data indicating that artificial insemination protocol can cause greater chances of pregnancy than the natural process during summer.

2.2. Dairy Farming Features. Internet of things and data-driven techniques are creating greater opportunities for smart dairy farming. Different features and their benefits are described in Table 4.

Table 3: Comparative analysis of different researches on dairy farms.

Researches	Smart monitoring		Cow observation		Feeding		Milking		Reproduction		
	SmartHerd	Decision support models	Fog-based platform	Wearable and nonwearable sensors	Ontology feed efficiency	FeedWatch method	Robotic milking	Haar cascade classifier	Wearable sensors	Fertility management	AI breeding protocol
[20]					✓						
[21]	✓		✓								
[22]				✓					✓		
[23]									✓	✓	
[24]			✓							✓	
[25]						✓					
[26]		✓			✓						
[27]		✓				✓					
[28]		✓					✓				
[29]								✓			
[30, 31]											✓

Table 4: Feature of SDF and their applications.

SDF feature	Subcategory	Applications	Description	Benefits	Shortcomings
Smart monitoring	Position Location Tracking	Geofencing RFID autotracking	Approaching and treating each animal individually	Low labor cost Less use of resources More productivity Improved cow health Detection of disease at early stage Low rate of death	High setup cost
Cow observation	Activity observation Behavior observation Body temperature	Sensor-enabled technology Automatic disease detection	Milk yield, milk conductivity, animal activity		
Feeding	Nutritional management	Automatic concentrate feeder	Supply feed depending on yield		
Milking	Preserving milk Robotic milking	Automilking	Milking procedure according to the health and age of the cow		

2.3. Geofencing. Geofencing is an area-based technique in which an application or other programming techniques can utilize GPS, RFID, Wi-Fi, or cell information to trigger a premodified activity when a cell phone or RFID label enters or leaves virtual limit setup around a topographical area, known as a geofence.

In dairy farming, a farmer equips a herd of cattle with hardware device which consists of different sensors and GPS tracking unit. Sensors are used to track down animal health and other key behavior to increase output and overall animal wellness. Geofencing uses GPS network and other related means like Wi-Fi nodes and Bluetooth beacons to create a geofence around the farmer area; then the geofence is paired with animal collar and software application, and when the animal leaves that specific area, it triggers the alerts for the farmer.

2.4. Automatic Disease Detection. In dairy farming animals can get various diseases due to numerous reasons. When there are a lot of animals, to check every animal daily is impossible and time consuming. It is a lengthy process and a difficult task to do individually and manually, and the animal's disease is also contagious, so if not caught in time, the other animals can also be infected, causing loss. Yield of milk can also be monitored and controlled, and any minute change in animal behavior can also be recorded. Therefore, to cater for this situation and find automotive way of monitoring animals' health, we move towards automatic disease detection.

An animal suffering from any disease changes its daily routine habits like lying down on different area, splitting itself from herd, or changing its eating habit. Sensors that detect changes in animal body make it easy for a farmer to detect and treat that animal. Mounted sensor can sense the behavior of an animal and keep record of it. These types of records help us in making future decisions like calling a doctor. Any abnormality in this pattern is easily detected with the help of sensors, and the farmer will be alerted through messages or other means. For example, the farmer can analyze any disease with the help of accelerometers measuring animal movement, and activities can be captured, for example, whether the animal is less active compared to its daily routine. Just like any other sensors (e.g., temperature sensors, load sensors, microphones, and heartbeat sensors), these sensors can record animal daily life behavior such as disease symptoms, temperature change, mooing, body weight changes, and pulse rate change.

2.5. Milking. Manual milking in a dairy farm is very time consuming and slow procedure. The preserving process of milk is also not hygienic. Manual process can cause bacterial infection in milk. IoT has solved this problem more efficiently, reducing cost and manpower, by introducing automilking. If the temperature is not favorable, the chances of milk getting spoiled are very high, but automilking can automatically preserve the milk by using different smart cooling tanks. Common automilking systems rely on two components: computer and special herd management software. Automilking is further divided into several tasks like collecting the animal, cleaning the animal before milking, attaching the milking equipment, extracting milk, removing the equipment, and routing the animal out of the special area. Milk production is dependent on the amount and quality of food given to the animals. Every cow in herd is different; some can be suffering from any disease, some are immature, or some can be pregnant. Each cow has its own amount of nutrients requirement. To ensure that required nutrients are given to the animal, this cannot be done by simply looking at fodder; rather it has to be processed through a mechanized system that will show the amount of carbs and proteins given to the cow.

2.6. Automatic Water and Food Supply. Water is an important nutrient for all animals. For the welfare and profitability of the animals, it is important that cows should have sufficient quality water. Milk contains almost 87% water. The water requirements are closely related to milk production, the moisture content of the feed, and environmental factors such as air temperature and humidity. The maximum cattle water supply network normally occurs during the highest feeding period. Automatic irrigation system is standard in most farms because it is practical and efficient. The system consists of an insulated floor and a heated bowl, which automatically fills with water from a pressure line. A float valve regulates the water level in the bowl. A thermostat set to 4 to 6° C regulates the water temperature in the bowl.

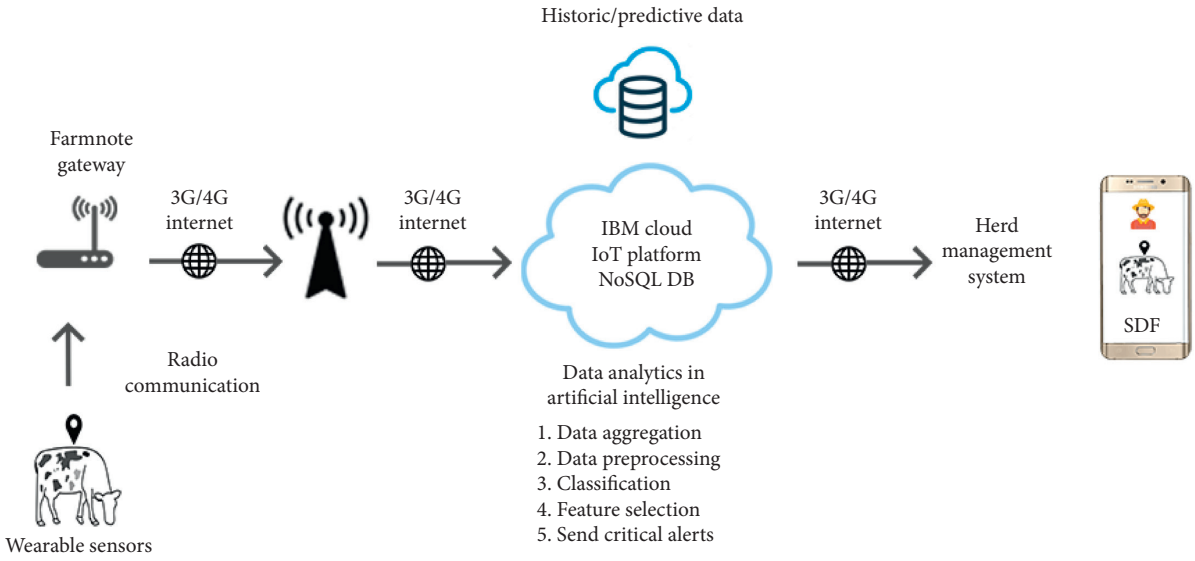

Figure 3: Framework for SDF.

Food is necessary for nutrition because it determines the amount of nutrients available to the animal for health and production. Actual or valuable food prevents underfeeding or overfeeding of nutrients and promotes the effective use of nutrients [32]. Underfeeding of nutrients limits production and may affect animal health. Overfeeding of nutrients increases feed costs, can lead to excessive nutritional load of the environment, and can be too toxic or dangerous to health.

2.7. Framework for SDF. This research focuses on livestock farming and proposed a framework with different levels. The overall architecture has been described in Figure 3. A wearable sensor for capturing data from cows will send data to the nearest gateway and, with the help of Internet, the data will be transferred to a base station. The base station sends the data to cloud, and the cloud will analyze data using different techniques and methods. IBM cloud with IoT-based platform analyzes the data with respect to different procedures; for example, when the sensor detects the cow hunger need, then the automated system will feed the animal. Smart dairy farming which is IoT enabled has some herd management techniques for maintaining the logs and historical data.

With this data the farmer can also predict the future data according to the environment of the cow. After analyzing the captured data, the cloud will send the alerts to the farmer for assisting the cow. This herd management system can be applied to large-scale dairy farming when there are a lot of animals. The system will automatically detect the need and send alert to the farmer. There are many factors that can cause lower milk production, but this overall architecture can create a comfortable environment for a cow. It will be helpful for cows and ultimately can increase milk production.

3. Conclusion

In this modern world, dairy farming is an attractive business that can be supported to improve the economic conditions of a country. This research focuses on different automated techniques like milking and feeding. These two techniques are the key efficient techniques that can be the future of a smart dairy farm. Efficient feeding and technological drinking method can lead to better nutrition of cows, which can be ultimately the reason for more milk production. Furthermore, a framework that can help a farmer in increasing production of milk has been proposed. The proposed system is an overall architecture for better adoption of the latest techniques for improving feeding and milking procedures. The system with overall architecture, better adaptation of technology, and versatile design can make IoT-based farming more efficient. Although it may require heavy investment in initial stages, later on, the improved technological infrastructure can make balance between the invested amount and the earned amount.

Data Availability

Data sharing is not applicable to this article as no new data were created or analyzed in this research.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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