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Enhancement of Livestock Production Using High-tech Techniques for Hydroponic Folder Production and Movement Control

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ABSTRACT

An increase in food production is now a must for researchers in order to meet food production for the world population. Research in smart agriculture has greatly helped in addressing various challenges facing farmers which include food wastage, sub-optima yield, pest and bug management, farmer-herder crises control, and many others. Monitoring of livestock movement is an essential aspect of smart agriculture, which gives livestock farmers maximum return on investment in livestock farming. This is also allowing farmers to manage and protect their herds efficiently from animal rustlers, reducing the herder-farmer crisis, and increasing animal and dairy food production by leveraging on the advanced Internet of Things (IoT) technologies. Moreover, animal production is largely depends on the kind of nutritious fodders and their environment which responsible for their increase in food and dairy production. This work uses long-range wide area network (LoRaWAN) techniques to track livestock by providing real-time data on animal location at every instant. Also, the use IoT in fodder production is explored in this work. A sensor device is attached to the animal body which communicates to the gateway while the data collected is transmitted to the cloud server. The server then communicates with the registered mobile phone number registered on the server by indicating the location of animals at every instant. Also, the LoRaWAN technology is used in fodder crop production to enable remote monitoring and control of various aspects of it rearing. By utilizing LoRaWAN, farmers can gather data from sensors deployed throughout the farm, analyze its, and make informed decisions about irrigation, fertilization, and other practices related to high-tech fodder production. Using these techniques, will affect the quality and quantity of fodder produced and bring a reduction in the farmer-herder crises.

1. INTRODUCTION

Smart agriculture, also referred as precision agriculture, uses latest technology and data analysis approach to optimize farming practices, increase efficiency, and maintain sustainability. This is achieved by enhancing animal health, productivity, feed quality, and increase in meat and dairy production [1]. Additionally, smart agriculture reduces the waste of agricultural consumables, such as water and land, agricultural inputs while enhancing environmental quality. As a result, using smart agriculture techniques will effectively enhance livestock management, leading to higher productivity and efficiency in livestock production, improved animal product quality, and increased environmental sustainability [2]. More so, the application of recent technology to traditional techniques elevates all facet of food production activities resulting in increased production, superior product quality, and improved environmental sustainability. This signifies a transformation shift in the running of farming activities especially livestock industry [3,4].

Smart agriculture uses latest technologies such as sensors, unidentified area vehicles (UAV), robots, drones, and artificial intelligence (AI) in order to enhance farming output and ease all aspects of farming operations. To Achieve these goals, Mohamed, E. S et al., 2021 and Javaid, et. all., 2023, discussed the application of smart agriculture in monitoring livestock health, automating some other tasks such as feeding and watering, and animal behaviour, consumption pattern, and analyzing it to make informed production and management decisions. Technological advancements ensure that smart agriculture will be crucial in addressing livestock production challenges and enhancing production quality and efficiency in near future [7]. Smart agriculture is a promising technology with the potential to improve the livestock industry significantly.

Because smart agriculture uses data-driven techniques and state-of-the-art technologies to transform animal farming, it is essential to use it to increase animal productivity. This subject is important for improving animal welfare, resource allocation, and agricultural sustainability. It offers viable ways to reduce the negative effects on the environment while satisfying the growing demand for food worldwide. Moreover, it presents chances for farmers and industry participants to improve their methods and adjust to the always-evolving terrain of contemporary agriculture [8,9]. With the potential to make animal husbandry a more productive, efficient, compassionate, and sustainable sector, smart agriculture is the way of the future. It uses data-driven techniques and state-of-the-art technologies to optimize and increase the precision of animal farming while lowering its environmental effect. Through the use of technology and data, smart animal husbandry improves sustainability, efficiency, and welfare while tackling environmental issues and the world's food demand with creative solutions for a more promising agricultural future. Furthermore, by improving productivity, sustainability, the creation of nutritious feed, and animal welfare, smart agriculture has enormous potential for livestock farming. For it to be widely adopted, issues with pricing, data management, and connectivity must be resolved. By putting the recommended solutions into practice, the agricultural industry may fully realize the potential of intelligent animal farming, supporting the objectives of sustainable development and enhancing total farm productivity.

In order to maximize all of the processes involved in livestock management, this work suggests IoT-based methods to improve the experience of livestock families in terms of improving livestock management, tracking livestock, security management, and fodder production.

The rest of this work is organized as follows. Section 2 present the system model, section 3 discusses the operation of the model discussed in section 2, section 4 discusses the technology adapted while section 5 concludes the paper.

2. ANIMAL TRACKING

2.1 Methodology

IoT refers to a network of physical devices embedded with sensors and connected to the internet, enabling real-time data collection and sharing. In animal tracking, the commonly used electronic devices are collars, RFID tags, or implants that collect data such as location with accurate coordinates and health metrics. The diagram below shows the interconnection between various network devices used in monitoring livestock movement through various technological inventions.

Figure 1: An IoT Livestock Management setup

Over the past years, there has been a sharp rise in the usage of precision technologies for animals kept in specific confinements in agricultural systems. Animals are kept within a specific range for a variety of reasons, including production efficiency, safety, and health management. Controlled feeding, waste management, and disease prevention are made possible by confinement, which raises production output per unit of input. Effective implementation of these technologies is hampered in large-scale livestock production systems by the absence of networking, handling facilities, and frequent animal contact. Effective wearable sensors must have a dependable power source, a high data rate, low power consumption, and the ability to operate over long distances in a network. Range Wide Area Networks (LoRaWAN), which can send small data packages over great distances, are used by many Internet of Things applications. For large systems, this networking technology offers a viable substitute for the Wi-Fi or cellular networking options now available.

2.2 System Overview

The sensor suite included three primary elements: the wearable sensor, the gateway, and the cloud-based server. The sensor was comprised of an Arduino-compatible microprocessor, a generic MPU9250 motion sensor which contains a 3-axis accelerometer, a 3-axis magnetometer, and a 3-axis gyroscope, a generic GPS receiver, an RFM95W generic LoRa radio. The sensor was powered using a USB cord connected to a battery. The microprocessor was designed for flexible programming using the open-source Arduino Integrated Development Environment (IDE) software. The central processing unit of the wearable sensor used an Arduino-compatible microprocessor with 64 MB of flash memory and 2 MB of random access memory (RAM). During data collection, the microcontroller was connected to a computer via a mini-USB. The MPU9250 and GP-20U&GPS, two sensing devices that serve as motion sensors and GPS receivers, respectively, comprised the wearable sensor. The MPU9250's output is controlled to 4 kHz for the accelerometer and I kHz for the gyroscope. Arduino code controls the communication between the CPU and the inertial measurement unit (IMU), allowing the user to modify the code as they see fit. The final component of the wearable sensor was an RMF95W LoRa radio. The radio operates at 915 MHz and is capable of sending data packets up to 256 bytes. The radio requires a 3.3 V power supply, weighs 3 g, and is 16 mm square in size. The radio also leverages SPI communication to link with the microcontroller to facilitate the transfer of the data from the microcontroller out through an antenna. Flexibility in the functionality of the wearable sensor can be accomplished by changing a number of parameters within the code as well as the frequency of sampling data. For example, the delay statement at the end of the loop can be used to adjust the reporting frequency of the sensor. To report more frequently, the period should be reduced. Additionally, the out string can be adjusted to add or drop data from the reporting protocol. Finally, statements can be added before the delay statement to sleep the sensor between reads to help reduce power consumption.

2.2.1 LoRa Gateway Setup

In Smart Farming environments, IoT technologies have previously been used to facilitate monitoring traceability in the value chain, which enables producers to optimize their production processes (Assimakopoulos et. al., 2024). Within the agricultural context, LoRa being is a low-powered, long-range wireless communication system which offers a good infrastructure for loT (Augustin et. al., 2016). The LoRa coverage range varies from 2 to 5 km in urban areas to 20–25 km in rural environments (Augustin et al., 2016), making this technology the most feasible for rural areas considering networking demands of at least 10 km in small-pasture. LoRa gateways collect data from LoRa end devices by receiving LoRa radio signals and then relaying that data to a network server or cloud platform via IP-based connectivity. This process allows LoRa networks to collect and transmit data from remote or distributed sensors, enabling applications like smart movement monitoring, industrial automation, and environmental sensing. To connect the device to the WiFi connection provided in the barn, the gateway was initially set up by connecting it to a wired Ethernet connection via the wide-area network (WAN) connector. The gateway remained connected to the WiFi network after it was first connected, and it was powered by plugging the device into an electrical outlet during the experiment. The gateway was configured to forward packets to an open-source Internet of Things application that uses the machine-to-machine IoT communication protocol (MQTT) to store and retrieve data following manufacturer standards. The network can function with other MQTT applications and other custom servers, even if this server system was just used for demonstration purposes.

3. High-tech Hydroponic fodder Production

3.1 System Architecture

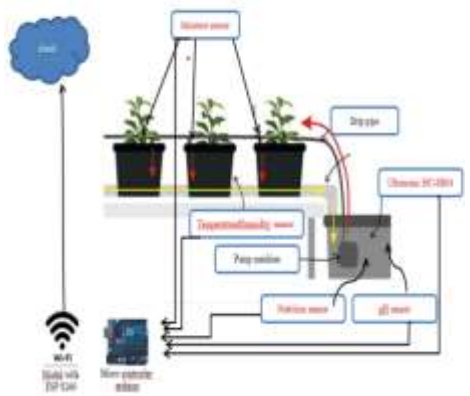

Figure 2: The architecture of Hydroponic Fodder System (https://www.researchgate.net/publication/335793556)

The Figure 2 shows architecture for IoT-based proposed hydroponic fodder production. Arduino uno EEPROM 1 KB (ATmega328P) random access memory is used as a primary controller for all the sensors and actuators, and to send data to the firebase which acts a cloud. The Node MCU is a microcontroller device that facilitates the integration of IoT functionality and the interface of several sensors and actuators. NodeMCU is the slave and Raspberry Pi is the master. The message queuing telemetry transport (MQTT) protocol, a common messaging protocol the Internet of Things, is used to communicate between the Raspberry Pi and Node MCU. This system interfaces a variety of sensors and actuators using four NodeMCU boards. The DHT22 sensor, which measures moisture, and the thermistor, which measures ambient temperature, are both found on the original NodeMCU board. Additionally, it is connected to a BH1750 sensor, which measures the amount of light in the surrounding area.

Since it keeps an eye on the crucial variable of the moisture content present in the hydroponic setup—which determines how best to manage the water requirements for the complete hydroponic fodder system—this initial NodeMCU board serves as the main driving board. The real-time clock (RTC) module, float switch, and pH sensor are all linked to the second NodeMCU board. To assist the software in carrying out time-dependent tasks, the RTC module records the most recent updated time and date, and the float switch measures the level of water in the barrel. If the pH sensor probe is submerged in water for longer than twenty-four hours, it will be harmed. Hence the water from the barrel will be sent every hour to a small chamber that contains the pH and turbidity sensors for measurements and the water will be drained after 10 minutes. The measurement data from the sensors will be sent to the Raspberry Pi 4 controller. The timing and sequencing of these step-by-step procedures will be taken care by the RTC module. The third NodeMCU board consist of by turbidity sensor the RTC module. Turbidity sensor is used to measure the total dissolved solids in the water and this data can be related to the total nutrient content present in the water. As like the pH sensor, the Turbidity sensor cannot be inserted inside water for more than 24 hours. Hence the turbidity sensor is also kept in the same chamber where the pH sensor is placed and sends data every one hour with the help of RTC module. The fourth NodeMCU board is connected to the relay board, which controls all the solenoid valves and water pumps. The first three relay switch is supplied with AC for the motor pump, AC solenoid valve and lights. The next five relay switch is supplied with DC for 24 V DC solenoid valves.

3.2. Design Methodology

The sensors and actuators along with their signal flow for the proposed hydroponic setup are shown in the block diagram of Figure 3.

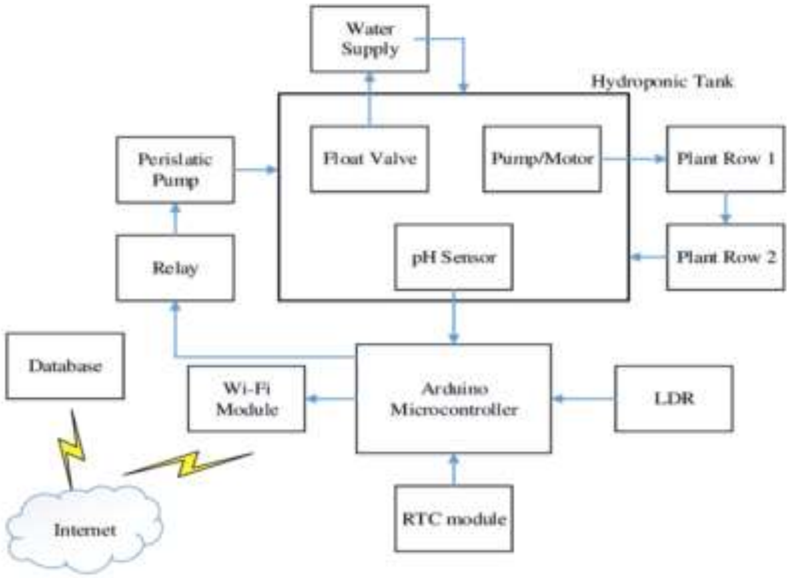

Figure 3: The block diagram of proposed hydroponic setup .

The block diagram shows the direction of signal transmission and reception between the sensors and actuators with the microcontroller and subsequently to the cloud. Raspbian operating system is used in the Arduino Microcontroller. The Raspberry Pi may be programmed to carry out all necessary tasks using the IBM-developed Node Red node-based programming environment. As a result, Node MCU boards that are programmed using the Arduino IDE become slaves while Node Red becomes the master in the Raspberry Pi. The full suggested hydroponic farming system, including all of its sensors, actuators, and other parts, is represented virtually. For storing water and fertilizers, a 200-liter barrel—a cylindrical container—is used. A 0.5 hp water pump is used to pump the water-nutrition combination within the barrel, and four float switches are installed inside to check the water level as seen in Figure 3. Adjacent to the barrel a separate enclosure is used to house the a pH sensor and turbidity sensor. For every hour with the help of a DC solenoid valve, water will be sent from the barrel to the enclosure housing a pH sensor and turbidity sensor for monitoring the acidity, and clarity of the liquid. A solenoid valve is used for supplying water to the barrel from the water tank whenever the water level goes down and with the help of fogging nozzles the nutrient-water mixture will be sprayed on the fodder crop. The DHT 22 and BH1750 are two sensors utilized to measure moisture, temperature and ambient light respectively. The sensors are divided into two parts with DHT 22 and BH1750 placed adjacent to the hydroponic rack setup and the pH sensor, turbidity sensor and float switches were placed close to the barrel. To monitor this entire hydroponic setup and surrounding environmental conditions a camera namely ESP 32 cam is utilized. The sensors are kept inside an enclosure in order to protect them from direct sunlight during operation. The frames which support the fodder trays are designed using polyvinyl chloride (PVC) pipes. The reasons to choose PVC pipes for frames are to avoid any fungus or algae formation in the frames. The trays and barrel are also made of the same PVC material because of its inherent advantages.

By using the process that is connected to the internet where the users can view and monitor the process via a registered mobile line. The based on the scheme of the system proposed above it is expected to reduce the level of damage to plants due to irrigation management.

The use of IoT technology with sensor sensors implanted in non-circulating hydroponic media provides fast information through the cloud and can be accessed on smartphones so it is expected to provide rapid handling if there are signs of damage to the hydroponic plants that can affect maximum yield.

4. DISCUSSION

Although commercial sensors for animal GPS monitoring exist, there is a need for more flexible sensor designs and more affordable options for research and industry applications alike. The sensors used in this study were able to provide detailed data on where individual animals spent their time within the pasture and how behaviors varied across a 24-hours period. The 24-hours data readings from the IMU also point to variations in how animals behave within the field throughout the day. Location-specific monitoring of animal movement has previously been conducted for livestock. However, most of these previous studies do not transmit data in real time. Using the proposed model will enable farmers to locate their animals at every instant and the food production will be increased by feeding the livestock with nutritious fodder.

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