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Artificial intelligence in poultry industry

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Abstract
AI plays a vital role in computer science as it enables the development of intelligent machines capable of performing tasks that typically require human intelligence. In the poultry industry, AI and sensors are used to assess and enhance the ventilation system, ensuring a comfortable environment for poultry. Its applicability in poultry extends to data collection on various aspects like microenvironment, behavior, health, and movement within the poultry house. Analyzing this data allows the AI system to quickly detect deviations and make improvements. It can also assess ambient conditions, poultry health, and equipment failures, and even perform tasks like removing dead birds and analyzing litter moisture. AI's benefits also extend to postharvest activities for broiler chickens and egg collection. It accurately grades poultry quality, streamlines processing operations, and provides valuable insights for enhancing efficiency. In commercial poultry farms, AI integration manages equipment automatically, optimizing performance and productivity by controlling machinery and equipment based on collected data.

Keywords: Poultry, artificial intelligence, GohBot, sensors

Introduction
In global egg production, India holds the third position, producing a staggering 82.93 billion eggs, and ranks fifth in broiler meat production, yielding approximately 4.4 metric tons as per the 20th livestock census. Poultry production practices have evolved with modernization, leading to a remarkable improvement in broilers' Feed Conversion Ratio (FCR), which has gone from 2.5 to an impressive 1.6. Moreover, the time taken to achieve the desired body weight in broilers has significantly decreased from 8 weeks to just 35 days (20th livestock census, 2019) [1].

The poultry industry's contribution to the Indian economy is noteworthy, amounting to about 70,000 crores in Indian rupees, and it continues to play a vital role as the nation's economy grows (20th livestock census, 2019) [1]. With the rise in per capita income, there is a definite anticipation of increased demand for poultry products in the future.

In the realm of computer science, Artificial Intelligence (AI) stands as an essential component, empowering the creation of intelligent machinery that are capable of performing tasks which usually required human intelligence. AI's broad scope facilitates the integration and analysis of information, enabling data-driven decision-making and enhancing overall business efficiency (Dwivedi *et al.*, 2021) [2].

A prime example of an AI application is evident in Google's Search Engine, which harnesses human intelligence to develop a platform where users can access information related to any topic by simply entering relevant keywords in the search box. Google's implementation of Artificial Intelligence significantly reduces the effort needed to obtain information from the vast expanse of the internet (Ilager *et al.*, 2020) [3].

Artificial intelligence in poultry industry
Recent advancements in machine technologies have significantly revolutionized daily activities in poultry production, aiming to reduce labor requirements, enable 24/7 monitoring, and facilitate remote reporting. Notable examples include the implementation of specialized robots like GohBot and Chicken Boy. GohBot, equipped with imaging sensors and machine learning capabilities, adeptly navigates poultry house floors, collecting floor eggs, and monitoring environmental factors such as temperatures, gases, and light levels. Chicken Boy, an innovative autonomous robot suspended from the ceiling, utilizes artificial intelligence and sensor technology to evaluate the surrounding environment, identify equipment malfunctions, monitor the health of poultry and perform tasks such as removing deceased birds and analyzing moisture levels in the litter. (Thornton, 2018) [4].

Utilizing Artificial Intelligence (AI) in the poultry industry offers numerous benefits. By reducing human interference on the farm, the risk of infections can be minimized. Moreover, machines and robotics often outperform humans in numerous processes, rendering them more efficient. The benefits of AI in the poultry industry will be explored further, addressing how it can create a positive impact in this domain.

To facilitate the seamless navigation of GohBot within the poultry house, it employs cutting-edge technologies such as indoor ultrasonic GPS and Microsoft Kinect depth data to detect obstacles. By employing path planning and obstacle avoidance routines, GohBot can autonomously operate while safely avoiding interactions with chickens. Additionally, clever routines, like the "nudging routine," gently move birds out of the robot's path, and a "Drive around" routine helps recompute the robot's path in case a bird doesn't move or encounters a static obstacle.

Farm Management

Big data is instrumental in improving farm management practices, particularly in the agriculture industry, where a significant amount of data is still collected manually. Recently, computers have been employed to store farm-related information, with data stored in spreadsheets or specialized software. However, the potential of big data lies in utilizing cloud storage to store vast amounts of information, which can be leveraged by machines and robotics to control critical parameters such as humidity, temperature and light.

Machine learning is becoming a potent tool that will revolutionize the future of farm management practices. With the help of machine learning, robotics can accurately monitor a wide range of important parameters essential for efficient farm management. AI goes beyond merely collecting data; it can process the information using data analytics, drawing from pre-stored data in the cloud. By employing AI to analyze data, instant decision-making becomes possible, significantly improving the farm's efficiency.

To illustrate, robots can be programmed to gather data on managemental and environmental levels inside the farm. This data is then processed, enabling machines to autonomously make decisions related to ventilation, a critical but repetitive task that impacts farm efficiency and profitability. Machine learning and data analytics efficiently manage such tasks, continuously monitoring farm activities, which can become cumbersome for humans.

Several universities are currently evaluating poultry farming control systems that use technologies like Zigbee and Raspberry Pi integrated with wireless sensors and GPRS. These technologies are expected to enter the poultry industry on a larger scale shortly.

Moreover, Artificial Intelligence can be applied to activities like feeding, watering, and sanitization, streamlining and automating these essential tasks. Data analytics plays a crucial role in predicting future outcomes by gathering and examining current data. For example, through continuous monitoring and analysis of present data, it becomes possible to make accurate projections regarding the weight of birds after a 30-day period. The implementation of AI in farm management will bring efficiency, accuracy, and faster decision-making to the system.

Disease Management

Disease management holds utmost importance in farming practices, as every aspect of farm activities is closely linked to it. Implementing machine-based disease management can be intricate, considering the diverse symptoms and numerous possible diseases. However, Artificial Intelligence (AI) is expected to simplify this process shortly, particularly through its role in assisting with diagnosis. This is where machine learning and big data come into play, proving instrumental in effective disease management.

Using cameras installed on farms, AI can swiftly identify issues like huddling and cannibalism among birds, promptly notifying caretakers to make faster decisions and minimize losses. Birds often exhibit unique vocalizations and abnormal behavior during illnesses. By feeding data on such peculiarities into the system, machines can be programmed to alert veterinarians immediately upon detecting any concerning behavior.

Moreover, mobile applications can aid pathologists and consultants in confirming diagnoses. These applications can utilize mobile cameras to provide better diagnostic insights. However, creating such applications requires a substantial amount of data. In-farm machine systems can leverage this data to diagnose diseases and promptly notify farm caretakers when intervention is required.

In 2012, Oxford University scientists conducted a noteworthy experiment called "Chicken Time Warp," revealing that the coordinated movement of a flock can help detect diseases up to a week before their actual onset. Such predictive capabilities can assist farmers in countering disease-related losses and have the potential to be applied to various deadly poultry diseases.

In summary, AI-driven disease management holds great promise for the poultry industry, with machine learning and big data playing pivotal roles in enabling early detection, accurate diagnosis, and timely interventions, ultimately leading to better disease control and reduced losses for farmers.

Trials and evaluation of nutrition and medicinal products

Artificial Intelligence (AI) offers remarkable efficiency in gathering and processing data, especially during or comparative trials of various products. Machines and sensors can monitor numerous data points simultaneously, a task that would be time-consuming for humans to handle. AI serves not only in gathering data but also streamlines the evaluation of results through analytics, presenting comparative outcomes supported by statistical analysis.

Furthermore, AI accelerates the evaluation of the impact of different feed formulations, a task practically unmanageable for humans at such speed. Programming and robotics, enabled by AI, contribute to enhancing breed genetics by identifying breed characteristics and simplifying decision-making in the selection process. These applications significantly reduce trial costs while ensuring precise results.

The costly affair of research and development (R&D) in any industry can be efficiently managed with AI's capabilities. AI empowers companies to conduct multiple studies within a single trial, a feat that would otherwise demand significant human effort.

In summary, AI's prowess in data collection, processing, and analytics greatly enhances the efficiency and cost-effectiveness of conducting trials, comparative studies, and research and development in the poultry industry. It streamlines processes, delivers accurate outcomes, and empowers better decision-making, leading to significant advancements and improvements in poultry farming practices.

Post farm activities

AI has already made significant strides in the poultry processing industry in many developed countries, leading to remarkable improvements in efficiency. Meat processing companies are exploring advanced technologies such as Artificial or machine vision to sort broiler parts and detect diseased carcasses. AI-powered machines can precisely distinguish between muscle mass and bone density, making automation of processes like deboning highly efficient through AI. Similarly, in the layer farming sector, AI is employed for tasks such as egg collection, grading, and rapid identification of high-quality eggs.

The integration of machine vision and smart automation has significantly improved the carcass quality and packaging in the poultry processing industry. Spectral-line Imaging systems have proven effective in accurately presorting broiler chicken. A leading player in the field, Tyson Foods, has successfully deployed a computer vision system equipped with cameras, machine learning algorithms etc. This system effectively monitors the quantity of chicken moving through the production lines. The company has plans to expand the use of smart automation and AI across all its plants nationwide.

With the growing global demand for protein, including in India and other regions, these AI-driven technologies are poised to have a significant impact on providing high-quality chicken and eggs at a lower cost. The poultry industry encounters several obstacles, including elevated raw material costs and the looming risk of diseases like Avian Influenza. However, AI's beneficial influence on the industry has the potential to enhance process efficiency, thereby increasing affordability of chicken and eggs for a broader segment of the population.

Miscellaneous uses

AI is a versatile technology with several applications that can impact the poultry industry in many ways. In particular, machine vision and smart automation offer significant benefits to feed and nutrition companies, vaccine companies and pharmaceuticals. These technologies improve accuracy, and efficiency, and enhance quality control in their manufacturing facilities.

Large integrators in the poultry industry encounter the difficulty of managing farms that are dispersed across various geographical locations. AI can help overcome this obstacle by enabling integrators to collect and analyze data from multiple farms, even if they are situated at various locations. Furthermore, AI enables remote monitoring of these farms, providing enhanced control over the entire production system, which includes layer, broiler and breeder farms.

Moreover, AI facilitates the rapid dissemination of new technologies. With AI, demonstrating the effectiveness of new technology becomes much simpler, and convincing stakeholders to adopt these innovations takes less time. This accelerated adoption of new technologies can lead to improved practices and efficiency in the poultry industry.

Devices Aiding in AI

Sensors

In the past few years, there have been significant improvements in sensing technology, marked by greater variety, precision, and cost-effectiveness. Wireless sensors, known for their versatility, are extensively employed across various industries such as agriculture, environmental and civil engineering and emergency management (Ruiz-Garcia *et al*., 2009) [5]. While their adoption in various sectors has been common for some time, their integration into farming practices is a more recent advancement. Initially, the main emphasis has been on utilizing these sensors to reduce operational expenses and improve the well-being of animals in the agricultural sector.

Environmental sensors

The health, survival, and productivity of broiler chickens are heavily influenced by environmental factors, particularly relative humidity, temperature and the duration of exposure to these conditions. Additionally, the presence of harmful gases like ammonia and carbon dioxide can have adverse effects on growth, feed conversion, and immune response in these chickens. Studies have shown that even brief exposure to high carbon dioxide levels in day-old chicks can result in higher mortality rates and changes in heart characteristics (Olanrewaju *et al*., 2008) [6]. Consequently, closely monitoring and regulating environmental conditions will play a crucial role in ensuring the well-being of the birds.

Although real-time multi-sensor monitoring and control of environmental conditions, beyond temperature, have not been widely adopted in commercial poultry farms, advancements in sensing technology have now made it feasible to create affordable systems for precise environmental regulation. For example, these multi-sensing systems can track various parameters like indoor temperature, differential atmospheric pressure, and air velocity within broiler flocks (Bustamante *et al*., 2017) [7]. By automatically evaluating the ventilation system's design and performance, these systems ensure that poultry are kept in a comfortable environment.

An additional illustration pertains to the integration of sensors capable of gathering data on relative humidity, temperature, ammonia and carbon dioxide concentrations simultaneously (Jackman *et al*., 2015) [8]. By coupling continuous real-time monitoring of the environment with sophisticated modeling tools, it becomes feasible to establish a warning system that detects any potential deviations from weight gains that are targeted. This system can also serve as an indicator of health or welfare risks for the poultry. Such an approach holds the promise of ensuring optimal and consistent environmental conditions for the birds.

Acoustic sensors

Bioacoustics is a scientific discipline that explores the sounds generated by living organisms and their relevance in biological contexts [9]. Among living beings, birds extensively depend on acoustic communication for social interactions and alert signaling (Corkery *et al*., 2013) [10]. Acoustic investigations can vary from straightforward evaluations of vocalization frequency disparities to more intricate analyses of sound characteristics. For example, Zimmerman *et al*. (2000) [11] effectively identified instances of food deprivation in broiler and laying hens by utilizing fundamental acoustic parameters like vocalization frequency.

The analysis of sounds has emerged as a valuable method for assessing the suitability of the thermal environment. Moura *et al*. (2008) [12] conducted a study where they evaluated the thermal comfort and performance of broiler chicks by analyzing the amplitude and frequency spectrum of their vocalizations. They observed the birds' behavioral responses while placing them in different environmental temperatures. The findings showed that as the temperature dropped, the

broiler chicks increased both the amplitude and frequency of their vocalizations, as they gathered together in a huddle to conserve heat. However, when the birds experienced thermal comfort, their vocalizations maintained a stable amplitude and frequency. This research demonstrates how sound analysis can provide insights into the well-being and behavior of broiler chicks in varying thermal conditions.

Furthermore, sound analysis has found applications in incubation to narrow down the hatching window, which refers to the time gap between the first and last hatching egg. This hatching window significantly affects broiler welfare and performance. Early hatching can lead to issues like dehydration and increased mortality, while late hatching results in reduced hatchability and lower chick quality. Moreover, differences in hatching time can influence feeding behavior in broilers [13] and cause heightened fearfulness in early-hatched males [14]. Hence, closely monitoring the final stages of incubation is vital to mitigate the risks associated with both early and late hatches.

Collectively, these research studies showcase the various possibilities of utilizing sound analysis to enhance the rearing conditions for poultry and identify behavioral concerns or vices. Given that sound technology has been in existence for a considerable period and certain parameters are straightforward to evaluate, there is significant promise for its feasible integration in commercial settings to enhance the overall health and welfare of poultry.

Movement sensors

Facilitating freedom of movement is a critical component of ensuring good animal welfare, as it is vital for animals to move without restrictions for their well-being. Nevertheless, several factors in poultry rearing conditions, including overcrowding, limited space in housing, and health issues, can impede their movement. Consequently, the extent of movement, or the lack thereof, directly reflects the welfare status of poultry.

Movement sensors have been employed to investigate various facets of movement in broilers and laying hens. One notable example is the use of piezoelectric crystals to evaluate locomotion issues in broilers, specifically focusing on analyzing the peak vertical force exerted on both feet during moments of weakness [15]. This approach enabled the identification of asymmetry in peak forces between each foot, which explained the uneven gait observed in male broilers. Such advancements represent a significant stride towards achieving real-time assessment of broiler gait [16].

In summary, movement sensors and related technologies play a crucial role in assessing and improving poultry welfare. By offering valuable insights into locomotion deficiencies, gait assessment, and potential hazards in alternative housing systems, the utilization of movement sensors contributes to the improvement of design and management practices focused on enhancing the welfare of broilers and laying hens. These data aid in identifying areas for improvement and implementing measures that prioritize the well-being and comfort of the birds (Daigle *et al.*, 2014) [17].

A) Sensors for health status detection

In carefully monitored experimental conditions, wireless devices with body temperature sensors and accelerometers have been used to identify highly pathogenic avian influenza-infected chicks up to six hours before they die (Okada *et al*., 2009) [18]. Later, utilizing a wireless 3-axis accelerometer and a radial lead thermistor, the same research team created more sophisticated apparatus. In order to enable the early diagnosis of avian influenza symptoms, this enhanced system communicated activity and temperature data to wireless sensor nodes. This technology proved the ability to detect anomalous states brought on by the disease twice as early compared to employing body temperature sensors alone, obtaining a detection ratio of 100% [19].

Although implementing such sensing equipment in large poultry flocks might be challenging, it could be effectively used on a subpopulation of sentinel birds, serving as a preventative or early detection strategy, particularly in high-risk areas. Additionally, as temperature fluctuations and decreased activity are common general symptoms for various diseases, this simple equipment could also serve as a alarmimg system for detecting other potential health risks.

B) Precision livestock farming

Precision Livestock Farming (PLF) is a management strategy in livestock production that utilizes principles and advanced technologies from process engineering. It involves automatic data collection, access, and processing using smart sensors to compile diverse data sources into a central database. The collected data is subsequently analyzed to develop an automated management system for the monitoring and control of animal health, animal performance and animal welfare. Rowe *et al*. (2019) [20] emphasize the automatic management of poultry farm equipment based on real-time data in PLF.

The poultry housing and equipment industry is continuously evolving, introducing new technologies that align with modern communications and ventilation systems. However, financial constraints in many developing countries limit the accessibility of such technologies for the majority of poultry producers. While certain technologies are still undergoing experimentation, there are various options avaliable that have demonstrated promising results and can be successfully implemented on commercial poultry farms.

Conclusions

There is a strong consensus regarding the significant impact of Artificial Intelligence in the poultry industry. Shortly, AI is expected to revolutionize the poultry sector and contribute positively by enhancing efficiency and accuracy at all levels of the industry. Many companies have already begun exploring the application of AI throughout the value chain and are actively implementing AI solutions.

The potential of Artificial Intelligence in the poultry industry is immense, as it addresses numerous challenges that cannot be overcome without the integration of machines and robotics. Embracing new technologies will lead to more affordable chicken and eggs for consumers by optimizing the entire production system's efficiency. Overall, AI's advancements in the poultry industry are set to drive positive transformations and unlock new possibilities for the sector.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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