Proceedings of the 4th International Conference on Machine Learning and Automation
DOI: 10.54254/2755-2721/2026.36401

Digital Technologies and Automation in Animal Husbandry: Applications, Challenges, and Future Trends

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Abstract. This study aims to examine how the application affects the animal husbandry industry across three specific areas: production, management and sales. This study discusses the development of animal husbandry. It divides it into 5 stages: learning to tame animals, developing techniques, achieving large-scale, high-density animal husbandry, the initial use of computers, and the current situation. By efficiently collecting and processing data, computers help farmers breed and manage animals and sell livestock. It can be shown that the use of computers and automation in animal husbandry has already become a trend. In the future, AI can also be used in this industry. However, the high cost of the device limited its widespread dissemination in order to build modern automated farms. Plus, most current research on AI-based precision livestock farming is applicable only to laboratory simulation environments. New technological development is necessary in the AI industry to enable AI to be used in complex real-world contexts.

Keywords: Automation, animal husbandry, precision livestock farming, artificial intelligence

1. Introduction

Animal husbandry is an important part of human civilization. Before Christ, people began to domesticate animals as an important meat supply or farming tool. In China, during the Xia Dynasty(2070-1600 BC), people domesticated animals. According to Dai et al., domestic dogs ate human leftover food at that time, and people grazed sheep and cattle on grassland [1]. It showed that humans at that time had already had some knowledge and experience to manage and feed domestic animals. After getting familiar with animal domestication, humans tried to improve animal breeds. Roman people also had a mature animal husbandry technique. According to Grau-Sologestoa et al., in the Late Roman period(mid 3rd-5th c.AD), Romans had already tried to improve their animal husbandry industry by both improving the animal feeding and choosing high-quality varieties [2]. In the modern times, because of the industrial revolution, people had the ability to comprehensively upgrade the animal husbandry industry. According to Woods, people concentrated more animals in smaller spaces and put them indoors so that animals would not be influenced by the weather conditions and people could manage them easier [3]. By the second half of the 20th century, the elementary combination of computers and animal husbandry had already emerged; farmers began to use computers to simply collect large amounts of data. People didn't structure this data in the way that can easily be applied, but this primitive use of computers can significantly help farmers.

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Nowadays, Computer science has a significant influence in each part of animal husbandry. For example, each animal individual's date like body size and weight will be recorded on computer; computers can help farmers raise animals standardized and unified by controlling the temperature and the humidity in livestock housing; the automation brought by computers can reduce labor costs and improve efficiency dramatically; the Internet and recommendation system can find potential customers. Generally, the application of computers in animal husbandry can be specialized in three dimensions: production, management and sales. With the development of the computer science field, the deep combination of computers and animal husbandry has already become an inevitable trend. This review aims to discuss how computers and automation change the traditional animal husbandry in management, production and sales.

2. Theoretical background

As mentioned in the earlier paragraph, humans have already learned how to domesticate and husband animals, and humans also improve their technique continually. 4000 years ago, the main methods people used to husbanded animals is that they grazed animals in a natural environment, and animals were fed with human's leftovers or the grass from nature. Domestic sheep, especially, ate the same food as wild deers [1]. In this stage, humans only have the ability to husband a small number of animals and the breed of the animals directly comes from the surrounding area. The primary actors in animal husbandry are individual farm households. Around 2000 years ago, although the Roman empire noticed that the importance of animal husbandry, limited by the technique, the only thing they could do was to import excellent varieties and offer higher-quality forage compared to the past. 200 years ago, British people began to raise and manage animals in big factories. However, it also brought some serious issues. The intensive husband animals ultimately contribute to a tragedy— the bovine spongiform encephalopathy in the United Kingdom. This event caused more than 3 million British cows to be killed [4].

Around 50 years ago, according to Putlerl et al., even though the computer had already been created, only a fourth of the remaining producers used computers in their daily work. What's more, most of them used computers only as an electronic ledger. They put their data directly into the computer and didn't use it as production decision aids [5]. Why did this awkward situation exist? From the 1980s to 1990s, there were serious issues that prevented the connection between computers and farming tools. Although at this period, the mechanics device with microcomputers became popular, the lack of a standardized and unified communication protocol significantly limited the development of automation. According to Spackmans and Jahns, each device was an information island. They couldn't receive and use the data from others [6]. It can be shown that in the animal husbandry industry, the electronic ear tag and the data from other devices couldn't be directly transported to the computer in the office, which forced farmers to perform secondary data entry through tedious manual processes. Lagging data caused by the long process ultimately impeded farmers to deal with the emergency such as illness. For example, when farmers get the data that illustrate that their pigs need some medicine to expel parasites, some pigs might have already lost significant weight and even died because of it. The financial losses and inconvenience caused by the untimely synchronization was the issue that challenged farmers for a long time.

3. Literature review

Currently, a new concept is becoming increasingly popular in the animal husbandry industry: Precision Livestock Farming (PLF). "PLF is used to describe the industry which can efficiently

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collect and apply data to increase the humans and animals' welfare and decrease the costs" [7]. This great development can be attributed to the application of computer science and automation in animal husbandry.

3.1. Production

The benefits caused by computers and automation in the production process can be divided into three parts: breed improvement, animal's health and environmental protection.

Computers can use and analyze the data from gene sequence. It can also collect data from animals' daily behavior such as how their weight increases and their body weight percentage. When the farmers want selective breeding to produce superior offspring, computers can use that data to identify which individuals have a better gene so that computers can offer a precise breeding suggestion. Computers can identify and rank the quality of lifestocks, high quality genes can be saved and used to breed to produce better offspring, and the rest of individuals should undergo chemical castration to improve their meat quality. Besides, in this study, when a large group of bulls breed, a computer can calculate which pairs of male and female bills will lead the inbreeding rate over 3.125% to prevent deformed offspring caused by inbreeding [8].

In animal husbandry, the livestock living environment has a deep connection with livestock' health. The indoor temperature, humidity, air and water, if one of these factors lose control, that is a serious damage to animals health. Fortunately, computers can detect data and control these factors in livestock houses automatically. About 75% of livestock houses use GSHP or ASHP. A computer can detect the indoor temperature; once it finds that the temperature is too low or too high, it can exchange the heat between inside or outside by the surrounding medium such as air and ground [9]. The data from low-cost non-dispersive infrared can be used by the computer to analyze the concentration of CO2 and data from tunable diode laser absorption spectroscopy can be used to determine the concentration of NH3. This gas is important to livestock's health, so the long term monitor is important. Computers can adjust air composition of air with this data to avoid bad influences on animals' health. With the help of cameras and animal ID, such as electronic ear tags or special mark on animals, computers can record the water intake of each individual [10], so farmers can detect the health condition of each individual.

The pollution to the surrounding area used to be a dramatic challenge to farmers. Animal feces might cause the water pollution to nearby rivers or air pollution because feces emit harmful gasses such as NH3 H2S ND ch4 [11]. However, this stress is greatly reduced by computers. Computers can analyze the component of the feces, and use this material to produce biogas for energy or fertilizer. What's more, computers can reduce land occupation in ranches and maximize resource allocation to reduce resource waste [12].

3.2. Management

Computer science and automation play an important role in farm daily management. The application also can be specified into three parts: animal behavior detection, scientifically-based automatic feeding and report making.

First of all, animals' behavior data is one of the most important things for automation. In a mature farm, there are usually thousands of livestock, which makes it impossible to check each livestock house everyday. It will increase the probability of an accident. By using sensors, such as microphones and cameras, people can long term collect data from Lifestick's behavior without interrupting their daily life. The study suggests that healthy chickens and ill chickens make different

DOI: 10.54254/2755-2721/2026.36401

sounds. Microphones can record these abnormal sounds; cameras can record the abnormal walking posture. Computers are able to analyze this data and give warm signs for farmers. This information can be used to determine whether the livestock is healthy or not. For example, computers can compare the food intake and water consumption of chickens to what they usually do. If a significant drop exists, humans can get this alarm rapidly. What's more, behavior data such as the distribution of chickens can also be used by the computers to check the quality of devices such as water troughs. If chickens abnormally keep away from one water trough, computers can send this message to humans [13]. The behavior data can easily be collected and used by computers to give human timely warnings to help humans manage their farm.

Secondly, computers can also arrange different types and amounts of food to livestock. Computers can detect the environmental data such as the temperature and the humidity to predict how much food livestock need, which can take good care of livestock and increase their welfare. Furthermore, computers can also identify the individuals' growth stages so that computers can offer individuals with feeds that include a suitable amount of food with needed nutrition. This kind of feeding can efficiently increase the nutrient utilization rate, decrease the feeding costs and help farmers manage their livestock [14]. However, the automatic feeding system also has some disadvantages. The high initial costs of the feeding device is unaffordable for individual farmers. Furthermore, the inaccurate recognition capability of the sensor is also a serious problem.

Lastly, the data such as the number of the livestock, the daily costs of the whole farm and the mortality rate can automatically be collected and analyzed by the computers. This data can be easily used by workers to make a professional report. It provides an intuitive view of the farm's past performance, thereby assisting management in making future decisions and plans. By isolating this information from the vast amount of raw data, computer systems can significantly enhance the farm's overall efficiency and contribute substantially to future planning and management.

3.3. Sales

Computers bring a new opportunity to livestock products selling. First, it offers a new platform for the products, helping more consumers get in touch with livestock products. By combining e-commerce strategy and traditional selling strategy, computers help farmers building online stores, and offer intelligent docking of supply and demand information [15]. In the past, there were informational barriers between urban and rural areas, which lead to a situation where high-quality livestock products such as milk and eggs cannot be sold directly from farmers to customers. Furthermore, the new platform created by computers also increases the risk resistance of livestock product selling. During covid-19, most of the industries such as service industry and catering industry face an industry shrinkage. People did like to buy food offline because it will increase the probability of being infected by the virus. Online selling can easily solve this problem. As a result, although the demand for livestock will decline, it will still remain in the positive range [16]. On the other hand, since computers process almost all of the data in farms, computers are able to calculate the initial cost, thereby better determining the product price and finding a clear position in the market.

DOI: 10.54254/2755-2721/2026.36401

4. Discussion & synthesis

4.1. Current situation

Computers and automation have a positive influence in the whole animal husbandry industry. Computers can offer rigorous and detailed data to form reports that help managers understand the current status of the farm so that they can make correct decisions. Intelligent feeding systems can improve livestock welfare and reduce costs. At the same time, computers bring a new platform for livestock product selling. Replacing human workers with mechanics can not only reduce the cost and mistakes, it can also decrease the possibility of the invasion of viruses and bacteria. Animals at early stages of their life are very vulnerable to viruses and bacteria, so in the past, people who enter nursery pens were required to perform full-body disinfection and put on sterile clothing and gloves. Replacing manual labor with machinery can solve this problem more easily. It also builds the bridge between farmers and consumers. Currently, for example, in China, lots of farmers are selling their products on social media. The direct-from-source sales method reduces the extra costs associated with middlemen between customers and farmers, so people in the city can buy better products with a lower price. Simultaneously, farmers can sell their product to distant areas. As a result, this model has greatly expanded the market for farmers. Nowadays, computers are comprehensively used in data analysis and large-scale devices control. For instance, in a modern large-scale egg farm, a single zookeeper can take good care of 50 thousands chickens, complete the collection of eggs and clean the chickens house with the help of computer-controlled equipment. Eggs roll from the coop onto a conveyor belt, and computers control the equipment to transport the eggs to a central egg storage facility at set times each day. Computers can also use indoor sensors to determine the environment inside the chicken coop and decide whether to increase the speed of ventilation fans, thereby controlling the indoor temperature and humidity. Generally, computers and automation can help farmers from breeding, raising, managing and selling livestock.

4.2. Future/trend

The application of automation and computers in the animal husbandry industry is an inevitable trend. Nowadays, the development of artificial intelligence(AI) also contributes to automation. PLF uses AI as an electronic brain to process large amounts of data. By studying the daily behaviors of livestock, AI can be used in animal health problems, because AI can detect abnormal behavior such as feeding, mating and rumination. Furthermore, based on the information from the internet, AI can give farmer suggestions regarding feed optimization, welfare assessment and reproductive support [17]. On the other hand, AI-Based PLF have the ability to process more complex and more comprehensive data. For example, AI can find the hidden correlations between environmental factors, animal physiology, and production activities. By processing different types of data, AI finds the connection between them so that AI can offer an accurate diagnostic report to humans [18].

4.3. Challenge

However, there are still some issues that challenge the application of automation and computers in the livestock husbandry industry. First, individual farmers and small farms cannot afford the automation farms. The original construction of modern automation farms required a large amount of money. The poor WIFI-service in the rural area will prevent data collection. Besides, the application of computers in animal husbandry will also increase the possibility of information leak. Important

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data such as animal health and daily management could be obtained illegally [19]. Furthermore, the use of AI in automation farms also faces some problems. Although AI performs well in simulated laboratory environments, whether AI can adopt the complex real-world environment is still a question. Visual modality still dominates; lack of multimodal combination and small amount real-world performance of AI in automation farms illustrate that the application of AI in automation farms is still an immature technique [20].

5. Conclusion

The review briefly illustrates the evolution of animal husbandry, and also points out the development and disadvantages of each period. Human civilization began to husband animals thousands of years ago. At the beginning, humans only domesticated animals around their habitat, and they strongly relied on their natural source. Animals fed with humans' leftovers or natural resources such as gasses. Thousand years have passed, around two thousand years ago, people have the ability to improve livestock breeding and feed quality. About 200 years ago, humans began to husband animals indoors. Animals wouldn't be influenced by the weather factors. Also, people can husband more animals in smaller areas. However, it also brings some problems, such as the rapid spread of the plague. 40 years ago, humans started to use computers in animal husbandry. Still, they use computers roughly; they only use computers as electronic ledgers. The lack of a unified port protocol undermined the data transition between computers and livestock tools. This review emphasizes how computers and automation influence traditional animal husbandry in three specific parts: production, management and sales. The study suggests that in animal husbandry's production, computers and automation significantly influence the livestock breeding, animals' health and environmental protection. Similarly, in the management part of animal husbandry, computers and automation facilitate the husbandry by collecting animals' behavior data, offering scientifically automatic feeding and making reports. Additionally, computers also help farmers expand sales channels and increase the risk resistance. Modern automatic farms with computers and automation have already become a trend. In the future, with the addition of more mature AI technology, animal husbandry will become more intelligent and efficient. Nevertheless, the expensive initial costs and the immature AI technique which is only applicable for laboratory simulation environments are issues.

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