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Automation Systems Used in Animal Shelters

Feride Didem Aydın[1*], M. Cüneyt Bağdatlı[2]

[1]Niğde Ömer Halisdemir University, Graduate School of Natural and Applied Sciences, Department of Interdisciplinary Digital Agriculture, 51240, Niğde, Turkiye.*
[2]Niğde Ömer Halisdemir University, Faculty of Architecture Department of City and Regional Planning, 51240, Niğde, Turkiye.

Abstract

Global population growth necessitates not only an increase in food production but also the adoption of more efficient, sustainable and advanced livestock production systems. In this context, the development of automation systems used in animal shelters has emerged as a process requiring technical expertise and professional competence. These processes require the accurate analysis of data and sound decision making by taking into account critical factors such as animal health and welfare and the use of human labor. Consequently, the use of automation systems in livestock enterprises is gaining increasing importance both worldwide and in Türkiye. This study discusses the functions and benefits of advanced technologies, automation, sensors and farm applications that have been developed and implemented in livestock enterprises from past to present.

Keywords: *Animal shelters, shelter automation, technologies used in animal shelters*

Introduction

As the course of life continues, the human population of the world is also increasing. Depending on this population growth, changes are taking place in the techniques used in agricultural and livestock production in order to meet humanity's food requirements (EFSA, 2009). From this perspective, animal shelters have evolved from small scale enterprise environments into facilities with higher capacity and more advanced technology. As the number of animals has increased, the importance of larger capacity and more technologically sophisticated shelters has also grown within this sector. Shelters are constructed as closed, semi open and open systems. In Türkiye and Europe, the number of enclosed shelters is quite high and one study reported that 60% of barns in Sweden are enclosed tie stall barns (Bilgin, 2024).

Recent technological developments and the increasing number of animals have provided the necessary platform for the advancement of animal automation systems. Automation systems used in animal shelters are intended to support animals' daily lives while reducing the need for direct intervention by farmers (Buller et al., 2020). Sensors are employed within these systems to help predict and prevent diseases, increase productivity, reduce human error and improve both production performance and animal welfare. The data obtained from sensors provide significant convenience and efficiency to personnel working in animal shelters across all operational processes (Neethirajan, 2020).

Today, various automation systems and sensor technologies are widely used to improve animal welfare, monitor health and increase productivity. For example, they provide the option of real time monitoring of animal movements, feed consumption rates, sleep patterns and environmental conditions within shelters. In particular, monitoring parameters such as temperature, humidity, air quality and ammonia levels is essential for animal health. Owing to the monitoring and management of this information, farms can achieve savings in input costs (Himu & Raihan, 2024).

The widespread adoption of digital technologies in agriculture has enabled the development of technology based devices and communication tools to support farmers' work processes. In this context, innovative solutions such as ear tags, robots, sensors, global positioning systems (GPS), animal tracking systems and virtual fences are being used effectively in modern agricultural practices (Aquilani et al., 2022).

Feeding Technologies

The main technologies used in this field are automatic calf feeding systems, precision feeding stations, feed pushing robots and feed mixing and distribution robots. Feeding occupies an important place in the daily routine. Even in modern enterprises, feeding is a highly time consuming operation. Because filling the mixing unit, transporting it to the shelters and distributing the feed are often carried out manually, the outcome largely depends on the operator's attention and care. With the use of these robots, labor is required only for preparing and cleaning the feed storage area, referred to as the "kitchen." At the same time, feeds are prepared through software assisted systems using feed mixing machines and are distributed in accordance with predetermined programs. Following feed distribution, feed pushing robots are activated to ensure that feed is distributed evenly along all rows (Figures 1–2). This process enables animals to access feed continuously and easily, thereby increasing feeding efficiency (Kaya & Örs, 2015).

Figure 1. Automated feed pushing robot (Haotun et al., 2018).

Figure 2. Feed Mixing and Distribution Machine (Erzurumlu & Şen, 2020).

Automatic Milking Robots

An automatic milking robot can perform the milking process more rapidly than manual milking machines and without requiring personnel; in doing so, it also eliminates the problems that arise when animals are forced to the milking area. The milking process begins when cows are trained to enter the stall structure. After the cow enters the stall, a camera is used to determine the positions of the teats. Following this procedure, the robotic arm takes the milking unit and moves it to the coordinates determined by the camera and milking is carried out under computer program control (Özüduruk, 2014). One such system is the automatic Lely Astronaut milking machine, which was introduced in the Netherlands, one of the leading countries in the agricultural sector.

Figure 3. Automatic Milking Robots (Kaya & Örs, 2015).

Use of Sensors in Animal Shelters

In animal shelters, numerous sensor technologies are used both to monitor animal health and to support practices aimed at increasing productivity. Information regarding these sensors is presented below.

Animal Health Monitoring Sensors

Sensors used in livestock farming are devices that transmit important data related to animals such as body temperature, step count and location to farm systems instantaneously and wirelessly (Figure 4). These sensors make individual animal monitoring more efficient while simultaneously facilitating management processes. The relevant sensors offer the possibility of performing measurement-based operations rapidly and in real time. Data obtained from sensors are processed quickly, thereby enabling the detection and assessment of animal health status (Özcan, 2022).

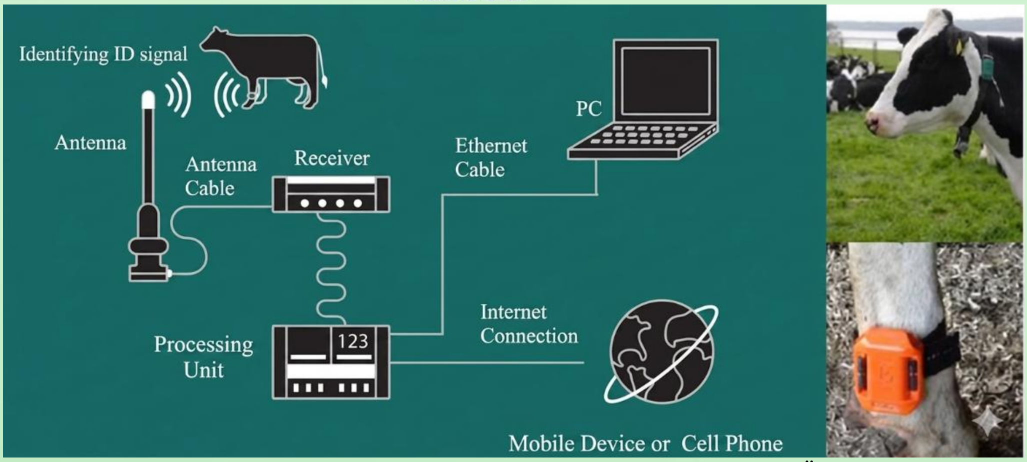

Figure 4. Use of a Wireless Animal Monitoring Sensor (Kaya & Örs, 2015).

Ear Tags

Monitoring animal behavior is of paramount importance for livestock health and surveillance. Accurate information regarding behavior, associated short and long term trends and variations can provide valuable insights into animal productivity, health and welfare. However, manual monitoring of animal behavior is time consuming, labor intensive, prone to human error and potentially disruptive to the animals. Consequently, with recent technological advancements, the utilization of electronic ear tags has emerged as a viable solution (Wang et al., 2023).

This approach represents the most widely adopted methodology within livestock housing. Beyond enabling individual tracking of animals within the herd, it facilitates real time, continuous monitoring of critical parameters such as estrus, pregnancy and health status directly through the system. Driven by its operational ease of use and recent technological advancements, the utilization of ear tags has emerged as a prominent choice for livestock producers (Çakmakçı et al., 2024)

In particular, the utilization of RFID and IoT based electronic ear tags stands out as a pivotal component of smart agriculture applications. These technologies enable the instantaneous monitoring of individual body temperatures and the real time localization of cattle within both pasture and shelter environments. This continuous surveillance mechanism plays a crucial role in preventing the spread of diseases across the herd by facilitating early detection (Peng et al., 2025)

Figure 5. Ear Tags (Wang et al., 2023).

When tracking location via GPS, the concurrent use of accelerometers enables the measurement of livestock's daily activities such as walking, ruminating and lying down mostly at various times of the day. This approach allows for the accurate detection of estrus and calving. Furthermore, abrupt behavioral changes can also signal the onset of parturition. Consequently, this helps farmers identify various parameters related to animal welfare, reproductive performance, health and the nutritional status of both individual animals and whole groups (Hlimi et al., 2024).

Use of Indoor NH_3 Sensors in Shelters

Since ammonia originating from livestock production can significantly contribute to environmental pollution, emissions must be mitigated across all potential sources, including housing systems, manure storage and outdoor grazing. In recent years, along with the increase in the livestock population, the atmospheric concentration of ammonia (NH_3) has risen. For this reason The measurement of NH_3 gas one of the gases such as methane, sulfur compounds and nitrogen oxides that are released in indoor shelter environments and are undesirable above certain levels is carried out through sensors (Monteny & Erisman, 1998). In particular, NH_3 is a hazardous compound and is known to pose a health risk to humans and animals due to its toxic properties (Algers et al., 2009). Different types of sensors, such as metal oxide, polymer, diode laser, electrochemical, surface acoustic and field effect transistor sensors are used to measure NH_3 gas (Kwak et al., 2019). In shelter design, the MQ 137 gas sensor, which can measure ammonia, has been used to determine the NH_3 concentration of indoor air (Figure 6).

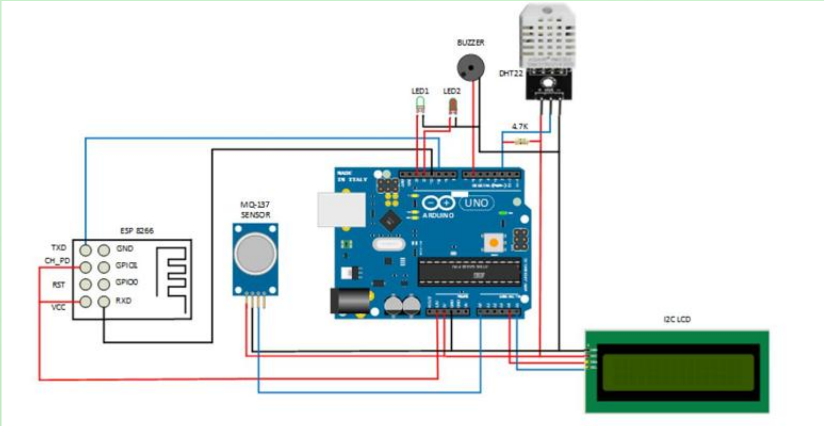

Figure 6. Circuit Diagram Used for Ammonia Measurement (Bilgin, 2024).

Use of Virtual Fences in Animal Shelters

Fences used in animal shelters are barrier systems designed to prevent animals from exceeding designated areas (Çakmakçı et al., 2024). These systems can also be created virtually by taking advantage of the capabilities offered by fixed or adjustable technologies. In particular, in virtual fencing systems, audible and electrical warning mechanisms integrated into sensors attached to the animal help redirect the animal when it violates designated boundaries. Operating through a two stage warning system, the technology first provides an audible warning when the animal crosses the fence boundary. If the animal does not heed this warning and continues to cross the boundary, a mild electrical stimulus is applied at a non harmful level to enable the animal to change direction (Jachowski et al., 2014; Lomax et al., 2019; McSweeney et al., 2020).

Microcontroller Board

A microcontroller board is used to evaluate NH_3 and sensor data measurements. The Arduino board is preferred for this purpose. Its ease of use and the fact that it does not require specialized hardware for programming distinguish it from other platforms, while also making it a popular microcontroller board compatible with different types of projects (Bilgin, 2024).

Temperature and Humidity Sensor

Temperature and humidity are among the most important parameters that must be monitored in animal shelters. Because they directly affect animal health, they should be tracked continuously. From this perspective, sensors are used to measure ambient temperature and humidity. One of the most widely used sensors for this purpose is the DHT22 temperature and humidity sensor. The DHT22 is an advanced sensing unit that provides a calibrated digital signal output. It is highly reliable and exhibits stable operating characteristics (Liu, 2013).

Body Weight and Condition Measurement Devices

Condition Scoring

Periodic assessment of body condition in dairy cattle makes it possible to identify body energy reserves, which are directly associated with health, reproductive performance and productivity and thereby enables effective herd management. Camera systems, usually positioned above the corridor leading to the milking system, capture top view images of animals' bodies, which can then be analyzed through specialized software on a computer, as shown in Figure 7 (Kaya & Örs, 2015).

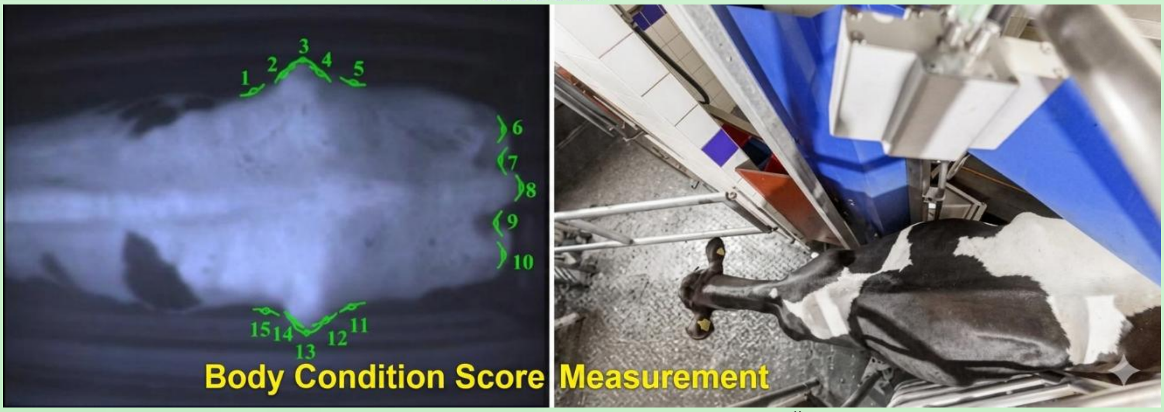

Figure 7. Body Condition Measurement (Kaya & Örs, 2015).

Scoring is performed according to the fullness between the spinal ridge and the transverse processes along the back. On 5 point scale, one body condition score (BCS) corresponds to approximately 40 kg live weight for Holstein cattle and 25 kg for Jersey cattle (Ministry of Agriculture and Forestry, 2017; Erdal and Ergüzen, 2020). In this context, the DHT22 sensor is widely preferred for temperature and humidity measurements because it offers high reliability, calibrated digital output and stable operating performance; the physical structure of the sensor is presented (Liu, 2013).

Weight Measurement

Together with condition scoring, the weight of an animal is an important indicator of its health status and value. However, only a small number of breeders weigh their animals regularly because the process requires substantial labor and appropriate weighing equipment is often unavailable (Frost et al., 1997).

The daily body weight measurement system functions as an important indicator in the evaluation of body condition score and energy balance. It generally performs the weighing of animals automatically through an electronic scale system placed on the path leading to the milking area (Figure 8). When the animal passes over the scale, the weight information is transmitted to and recorded in the computer together with the animal's identification number (Kaya & Örs, 2015).

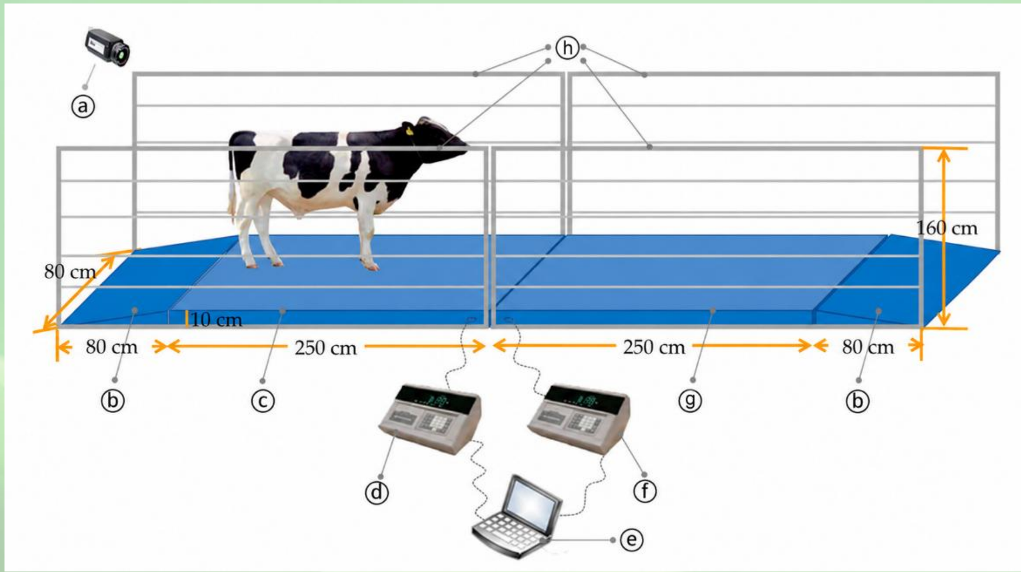

Figure 8. Cow weighing diagram: (a) camera, (b) slope, (c) dynamic weighing platform, (d) dynamic weighing indicator, (e) computer, (f) static weighing indicator, (g) static weighing platform and (h) guardrail (Yan et al., 2020).

Farm Management by Computer

Real time monitoring of animals has become possible thanks to advances in computer technologies and increasing data storage capacities. Today, computer programming technology has begun to be used extensively in animal shelters for data collection, analysis and the development of decision support systems. Applications of this technology in the livestock sector are also increasing rapidly (Li et al., 2021).

Monitoring of farm animals has become possible through Computer based programming systems integrated with fixed and mobile devices. Among fixed systems, cameras placed on shelter ceilings, passage points, or specific areas are prominent whereas mobile systems can monitor and analyze animal movement through technologies such as rail mechanisms, robots and drones (Çakmakçı et al., 2024). Through recording devices, images or videos in various forms and formats are captured and transmitted to the system software. Computers or cloud computing servers are used to process the collected data. Analyses carried out on these data enable operations such as identification, classification and modeling with the aid of machine learning algorithms (Li et al., 2021; Narendra & Hareesh, 2010).

Internet of Things (IoT)

These systems are also described as integrated sensor object and smart device based systems supported by artificial intelligence, in which components can communicate and operate with one another without the need for direct human supervision (Ambrosin et al., 2016). The use of IoT in livestock farming is a precision system employed to perform analytical measurements in order to optimize enterprise decisions (Abdullahi et al., 2020). IoT use in livestock production can be further expanded particularly in rural areas where herd grazing is practiced and animals are more likely to become lost, as it enables effective animal monitoring (Dlodlo & Kalezhi, 2015). In summary, IoT based devices are used in the management of data collection, analysis and decision-making processes related to farm animals.

Smart Dairy Farms

Smart dairy farm applications are emerging as an important solution to meet the increasing global demand for high quality dairy products (Akbar et al., 2020). The use of advanced data analytics and sensor technologies helps dairy farms become less affected by environmental factors while also enabling improvements in animal health. Especially since 2015, milk has become one of the most demanded products in the global market and one of the animal based food sources most affected by price fluctuations (Akbar et al., 2020).

Across the world, many dairy farms use these technologies not only to increase productivity but also to transition more easily to sustainable agricultural production methods. For example, smart dairy farms equipped with IoT based sensors and automation systems in countries such as the Netherlands and Germany both reduce production costs and enhance quality (Akbar et al., 2020).

The table 1 below presents the status of milk production and milk demand in nine different countries. When these data are evaluated, global milk consumption can be interpreted in relation to market significance as well as regional differences between production volume (tons) and milk demand (million tons).

Table 1. Milk Production and Demand Amounts of Countries (Akbar et al., 2020).

Country	*Milk Production (Million Tons)*	*Milk Demand (Million Tons)*
United States	3,4	14,6
Germany	1,6	4,9
France	2	3,9
New Zealand	1,8	2,8
China	4,7	6
India	16,5	8,4
Brazil	8,7	5,3
Pakistan	3,8	2,1
Bangladesh	1,5	2

Conclusion

The objectives of automation system applications used in animal shelters can generally be summarized as follows (Kopuzlu, 2023; Bewley, 2008):

- Reduction of the breeder’s physical and psychological workload,
- Improvement of the enterprise’s level of success and reduction of risk,
- The most efficient use of enterprise resources,
- Ensuring the highest possible compatibility of input factors with animals’ requirements,
- Providing support to humans in herd management tasks and the early diagnosis of diseases,
- Minimizing drug use through early diagnosis and preventive measures,
- Maximizing the utilization of each animal’s individual potential.

The benefits obtained from automation systems used in animal shelters can be stated as increased productivity, reduced costs, improved animal health and welfare, minimization of the effects of adverse environmental factors and more efficient management of production processes (Aydin, 2021).

These systems bring about substantial changes in health, reproduction and quality control. Especially in shelters where large groups of animals are managed, it may be difficult to examine each animal individually; however, through the data collection and analysis processes provided by automation systems, exceptions can be detected rapidly and managed more easily (Aydin, 2021). For this reason, while the care of animals and the monitoring of their health status can be followed more easily, the utilization of products obtained from animals can also be carried out more efficiently (Aydin, 2021).

Automation systems used in animal shelters make it possible to collect a wide range of data, including individual feeding, regular health monitoring, movement tracking, analysis of lying behavior, body temperature, respiratory rate and heart rate. These systems collect data at the individual animal level through devices such as pedometers, pressure plates and temperature and humidity sensors. In addition, important indicators of health and performance, such as rumination duration, locomotion ability and animal behaviors, can be monitored through image analysis. The data provided by automation systems enable the development of a proactive care strategy focused on animal health, thereby supporting the early detection of diseases and more effective herd management.

A well planned and properly maintained lighting system can also yield rapid benefits in animal shelters, both in terms of animal performance and for shelter personnel (Demir et al., 2020).

Declarations

Ethics Approval

This study does not require ethics committee approval, as it does not involve any experimental application on human or animal subjects.

Author Contributions

The authors jointly contributed to the study design, literature review, content analysis and manuscript preparation and they reviewed and approved the final version of the text together.

Conflict of Interest

There is no conflict of interest among the authors.

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