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# SMART TECHNOLOGIES AT LIVESTOCK FARMS

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***Abstract***

*At the livestock farm level, smart technologies are used mainly for identifying and locating animals, monitoring them to assess welfare and body condition, assessing and predicting performance, health and reproductive status. Data obtained using various measuring devices (sensors), most often appropriately transformed and integrated, enable early detection of physiological events that routinely occur in the animal's life (estrus, upcoming parturition), as well as undesirable events, such as metabolic disorders and diseases (mainly of the udder and limbs). Also, constant monitoring of animals, resulting in the collection of large sets of data supports the genomic evaluation of the breeding values. Thanks to smart technologies, it is possible to assess the correctness of nutrition, the quality of pastures and the impact of animals on the environment, including the amount of greenhouse gas emissions, as well as to control the microclimate of livestock buildings and to predict the economic efficiency of production. Moreover, these technologies are used for ensuring the safety and quality of animal products in the chain from the producer to the consumer.*

***Key words**: data sets, livestock, management, monitoring, smart technologies.*

## INTRODUCTION

The rapidly growing world population creates the need to constantly increase the supply of food products, especially in developing countries. Expert estimates indicate that global demand for animal products such as meat, milk and eggs will increase by more than 70% in the next three decades (Godfray et al., 2010). This results in the taking over of more and more areas for agricultural use and a significant intensification of agricultural production in many countries. The intensification of plant and animal production by increasing specialization, scale of activities and unit inputs, enables achieving high yields and usually improving economic efficiency. Unfortunately, excessive intensification of livestock production may lead to deterioration of animal welfare, health and longevity, contamination of soil and water with artificial fertilizers used in the cultivation of feed plants and large amounts of animal excrement introduced into the environment, increased emissions of greenhouse gases (mainly by ruminants), reduced biodiversity, lower quality of food products and, indirectly, also deteriorated people's health. Issues related to production conditions, product quality and the impact of farms on the environment are also the subject of concern in increasingly aware societies. Therefore, contemporary agriculture, including livestock production, faces complex economic, environmental and social challenges. It must reconcile the increase in the production of high-quality food and ensuring adequate profitability while limiting the unfavourable effects of the taken actions. The recommended solution is economically, environmentally and socially sustainable intensification of agriculture (Garnett et al., 2013; Ponisio & Kremen, 2016; Lovarelli et al., 2020).

Obtaining satisfactory results, both in intensive and more sustainable livestock production, requires skilful management of herds maintained in various natural, technical and market conditions. The use of scientific research results and advanced engineering and technical solutions has actually contributed to the enormous progress observed in livestock production over the last several decades. Proper herd management requires an individualized approach to animals, possible thanks to innovative engineering techniques and digital technologies, allowing for full automation of animal monitoring as well as the collection and processing of large production, physiological, behavioural and environmental data sets. Moreover, generating and sending electronically information supporting optimal decision-making as well as using automats and robots in many farm activities is increasingly common.

## MATERIALS AND METHODS

The combined use of sensor technology, the related algorithms, interfaces, and applications in livestock husbandry is called Precision Livestock Farming (PLF) (Kleen & Guatteo, 2023). According to Tullo et al. (2019) PLF can be defined as "the application of process engineering principles and techniques in livestock breeding for automatic monitoring, modelling and management of livestock production".
PLF consists in optimal, broadly understood, control of the herd and technical devices using real-time, comprehensive, automated monitoring of physiological, behavioural and production indicators for individual animals, indicators describing the farm environment and functioning of machines and devices, as well as collecting the information on economic, environmental and social phenomena that may affect the efficiency of livestock farming. PLF uses the Internet of Things (IoT), information and communication technologies (ICT) and cloud computing for collecting, processing, and transmitting information in electronic form (Benjamin & Yik, 2019).
Sensor technology enables comprehensive monitoring providing a huge amount of information (Big Data) about animals, farm environment, and broadly understood economic, environmental and social aspects of production processes. Big Data are large and complex data sets, requiring special tools and techniques for processing and analysis.
Animal monitoring requires their identification and location. For this purpose, collars with relatively large transponders using high-frequency radio waves (Radio Frequency IDentification - RFID) are commonly used. There are also miniaturized and cheaper devices that use low-frequency radio waves, such as sensors placed on the ear, intraruminal boluses or devices implanted under the skin. Data on animals and farm environment recorded by sensors placed on and inside the body of animals, sensors installed in buildings, machines and farm equipment, delivery vehicles and vehicles transporting animals to the slaughterhouse may be in numerical, visual or acoustic form. Monitoring techniques include the use of activometers, including pedometers and three-axis accelerometers, as well as wireless telemetry, cameras and 2D and 3D scanners, automatic scales with the function of measuring hoof pressure, as well as acoustic chewing sensors. Images and sounds are usually processed using appropriate algorithms to obtain numerical data that can be subjected to further analysis. Additionally, the data on climate and weather conditions, soil quality, crop volume, operational activities of enterprises, market situation and consumer preferences are collected.
The basis for Precise Livestock Farming is the use of artificial intelligence (AI) - a technology that, by simulating intelligent human behaviour, effectively supports the optimization of decisions and the automation of activities and processes in livestock management. According to Russell (2016), artificial intelligence is a set of methods combining data, algorithms and computing power capable of performing tasks normally requiring human intelligence, such as sensory perception, speech recognition, decision-making, and forecasting. AI includes machine learning (ML) and deep learning (DL) algorithms, with special application of artificial neural networks (ANN) (Berckmans, 2014) (Figure 1).

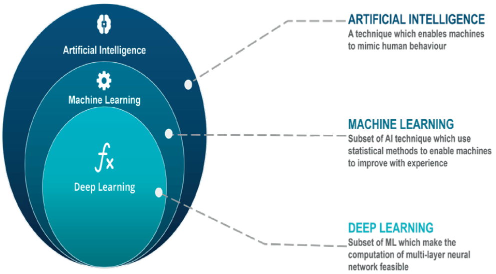


Figure 1. Basic classification of artificial intelligence

Machine learning includes automated analytical systems that learn themselves over time and as more data is acquired. ML tasks are classified into different categories - depending on the type of learning (supervised /unsupervised) and the learning model (classification, regression, clustering and dimensionality reduction). There are also learning models adapted to the implementation of specific tasks (Liakos et al., 2018) By means of self-learning algorithms, computers independently, without the need for programming, analyse data and, taking into account the variability of phenomena and requirements, automatically adjust models in order to acquire new knowledge and increase the ability to solve problems of detection, recognition, classification, prediction or decision choice. Machine learning techniques and algorithms are shown in Figure 2. When ML models encounter new data, they can adapt and use it in the analyses. This technique is closely related to data mining, conducted to obtain information and knowledge as well as search for patterns and relationships. The ability to predict events and identify risk factors is also particularly important (Akbar et al., 2020). The growing interest in ML results from the need to analyse increasingly larger data sets from various sources, including huge Big Data resources and the emergence of much more efficient computing technologies and much cheaper data storage platforms. However, Valletta et al. (2017), conducting an extensive review of the applications of machine learning to assess animal behaviour, concluded that the current data collection capabilities exceed the capabilities of their analysis using classical statistical methods. This applies especially to complex and multidimensional data sets, including traits with non-linear or difficult to determine relationships.

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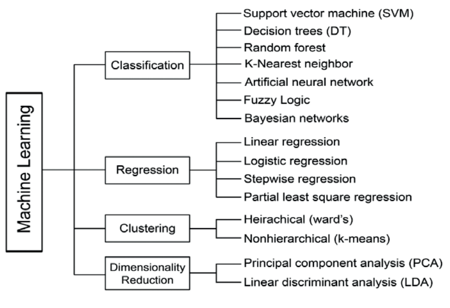


Figure 2. Machine learning techniques and algorithms (Cihan et al., 2017)

A subcategory of machine learning is deep learning (DL), based on artificial neural networks (ANN) (Lu, 2019). The structure of artificial neural networks consists of many layers of input, output and hidden data. When an artificial neuron receives a numerical signal, it processes it and transmits the information to other neurons that are connected to it. Just like in the human brain, strengthening neurons allows for better pattern recognition, knowledge acquisition, and overall learning. Huge amounts of complex and distributed data are used to gradually obtain more and more accurate results.

DL technology has greatly improved computers' ability to detect, classify, and recognize data, generally, the ability to "understand" it. It is widely used in areas that require operations on non-numerical data, e.g. image classify-cation, speech recognition, object detection and describing the content of data sets.

## RESULTS AND DISCUSSIONS

Modern livestock management involves an individual approach to animals and taking into account existing production, environmental, economic and social interactions. A great facilitation in this respect is the increasingly widespread access to intelligent engineering and information-communication technologies.

The application potential of technologies using artificial intelligence (PLF with Big Data) was demonstrated by Lokhorst et al. (2019) in a review of 142 papers published between 1994 and 2017. A significant increase in the number of publications was observed around 2010, and the largest share were the papers dealing with the application of PLF in dairy cattle. Most studies described the use of supervised machine learning methods, classification techniques and time series analysis algorithms. Slob et al. (2021), conducting a systematic review of 427 papers on the use of machine learning in dairy farm management, found that 55% concerned the detection of diseases, mainly mastitis, and the remaining two categories were the prediction of production volume (26%) and milk quality (19%). 23 algorithms were identified, among which the best results were obtained using decision trees. Based on 97 papers published between 2015 and 2020, Cockburn (2020) concluded that ML algorithms using integrated data from various sources are a promising decision support tool in physiology, reproduction, behaviour and nutrition of dairy cattle. Despite the wide use of this method, mainly for the prediction, most of the tested algorithms still did not demonstrate satisfactory correctness, which limits their implementation in practice. According to the author an improvement in forecast accuracy can be achieved by increasing the amount of training data, collected over a longer period of time and coming from a larger number of farms.

At the farm level, artificial intelligence is used, among others: for identifying and locating animals, monitoring them in order to assess and predict performance, well-being, condition, health and reproductive status, as well as for determining the level of greenhouse gas emissions or controlling the microclimate of livestock buildings. Data obtained using various measuring devices (sensors), most often appropriately transformed and integrated, enable early detection of physiological phenomena that routinely occur in the animal's life cycle (estrus, upcoming parturition), as well as undesirable phenomena, such as metabolic disorders and diseases (mainly udders and limbs). Also, they can be used for prediction of reproductive performance, production volume and its efficiency, assessment of nutrition correctness, pasture quality and environmental impacts, including greenhouse gas emissions, control of the microclimate of livestock buildings and improvement of working conditions on the farm.

Constant monitoring of animals and forecasting events by learning based on past behaviour, rules and available data is indispensable for supporting optimal decisions resulting in the improvement of performance, welfare and health of individual animals and the entire herds, as well as the state of farm environment, the increase in production and economic efficiency, and reduction of the negative impact of production on the natural environment (Halachmi et al., 2019, Neethirajan, 2020). Early detection of threats and deviations from normal states and possibly indication of their causes enable breeders to take appropriate preventive and adaptive actions. The use of modern technologies for monitoring of animals and environment in the so-called smart farms allow to carry out numerous tasks and processes using automated equipment and even robots. They include individualization of feeding, sorting animals, and controlling the microclimate of livestock buildings, among others (Cihan et al., 2017). Moreover, artificial intelligence is used to ensure the safety and quality of animal products in the chain from producer to consumer (Zhu, 2019).

The main areas of application of intelligent technologies in animal production are presented in Figure 3.

## CONCLUSIONS

The use of artificial intelligence, Big Data, the Internet of Things and Internet cloud computing for collecting, processing and transferring data and information on the farm and in the chain from producer to consumer, called "Smart Farming" (Intelligent Agriculture), is no longer just a futuristic concept, but it is part of the technological revolution, currently called Agriculture 4.0 (O’Grady & O’Hare, 2017; Rose & Chilvers, 2018; Wolfert et al., 2017).

Thanks to intelligent digital technologies, it is possible not only to constantly monitor animals, but also to comprehensively analyze production, physiological and behavioral data, which favors a more holistic approach to livestock management on the farm, during transport and slaughter. The modern technologies allow not only to better manage herds in various natural, technical, market and social conditions, but also to collect data used in the genetic improvement of production and functional traits. Summarizing, they significantly contribute to the increase in food production needed to feed the world's population, but also to more sustainable livestock farming owing to optimization of production efficiency in the context of expenditure incurred, used natural resources, appropriate animal welfare, quality of food products and protection of environment (Tedeschi et al., 2021).

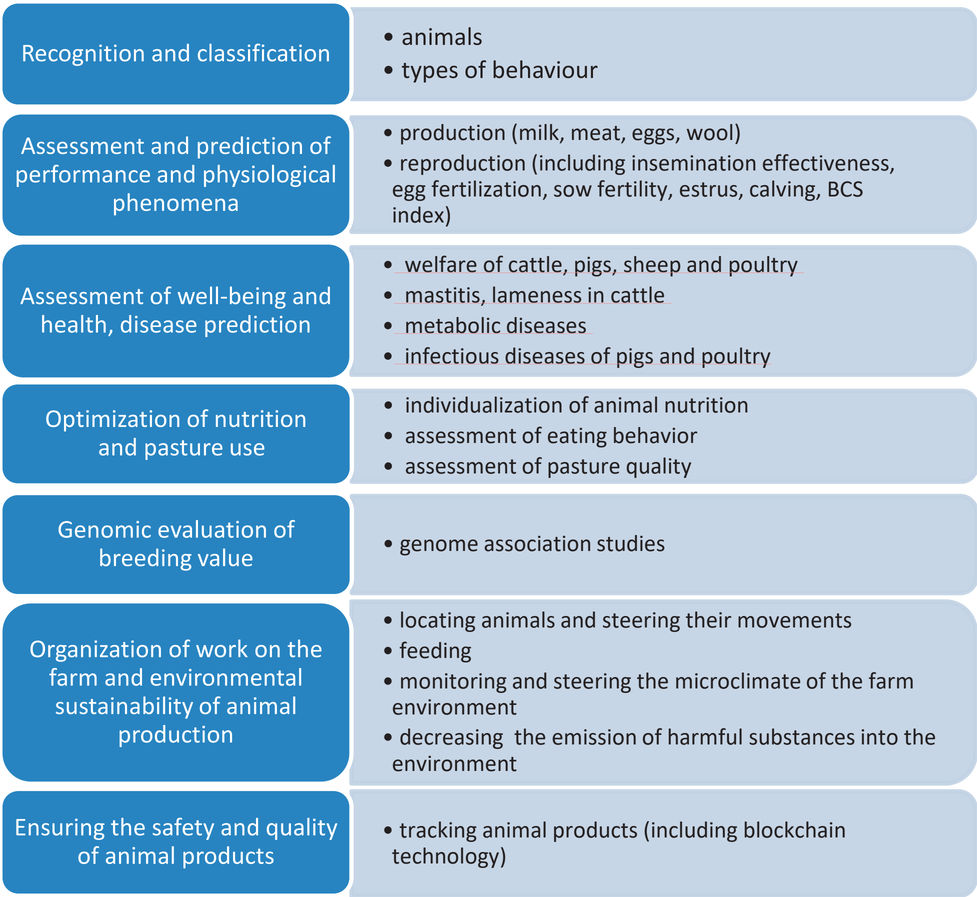


Figure 3. Main applications of artificial intelligence algorithms in livestock farming

An increased use of intelligent technologies in both intensive and more sustainable, and even extensive, livestock production systems will surely be continued but due to the still relatively high, although clearly decreasing costs, in the near future it will probably be limited to relatively large farms (Berckmans, 2014; Norton et al., 2019). An important driver may be the possibility of reducing employment as a result of using the innovative solutions in farm activities (Vaintrub et al., 2020).

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