Precision Dairy Farming: A Glimpse into the Future

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The adoption and use of technologies has made its way into our daily lives. For example, research has shown increased adoption and positive perception of the use of smartwatches to monitor our activity, heart rate, and sleep. At the same time, people have displayed increased acceptance and perception of the usefulness of virtual assistants that can be used to answer questions or manage our homes. Like our daily lives, the adoption of technologies in the dairy industry is also a reality. Utilizing technologies to monitor animals or resources with the aim to improve management and optimize dairy farm economic, social, and environmental performance has been defined as "Precision Dairy Farming".

Dairy farming is a challenging activity, especially when producers must deal with labor shortages, constant variations in milk and feed prices, and tight profit margins. At the same time, producers are challenged to manage more animals given increased herd sizes seen over the years. With that in mind, producers tend to seek novel farm and herd management practices to improve labor and resource utilization efficiency. A few commonly utilized strategies by producers to decrease the volatility of their profit margins are contracting milk prices or bulk buying commodities. While those are valid to reduce the susceptibility of the dairy farm to market-driven uncertainties, they do not aid producers in dealing with labor shortages, in dealing with a larger number of animals, or be sustainable in the face of increased uncertainty, global change, and the need to comply with always more challenging environmental regulations.

Therefore, some producers seek to invest in Precision Dairy Technologies such as wearable sensors and cameras to monitor and detect changes in the behavior, body composition, and physiology of cows and calves. Some producers may opt for the adoption of robotic milking and automated calf feeding systems to manage and monitor their animals. These technologies are capable of monitoring animals in real-time and on an individual level, generating data that allows farmers and consultants to make data-driven farm and animal management decisions. Traditionally, visual assessments are utilized on farms to record body condition and locomotion

scores or for observing animal behaviors associated with estrus or disease. Besides being labor intensive, visual observations are also subjective and generate information that is limited to the visual observation period. However, technologies are not only able to constantly monitor the animals, but they also do it in a more repeatable and less subjective manner compared to visual observations. Thus, in this introductory article, we explore a few of the current and upcoming Precision Dairy Technologies and briefly discuss how each of them can be used to monitor and manage dairy cattle.

Wearable Sensors:

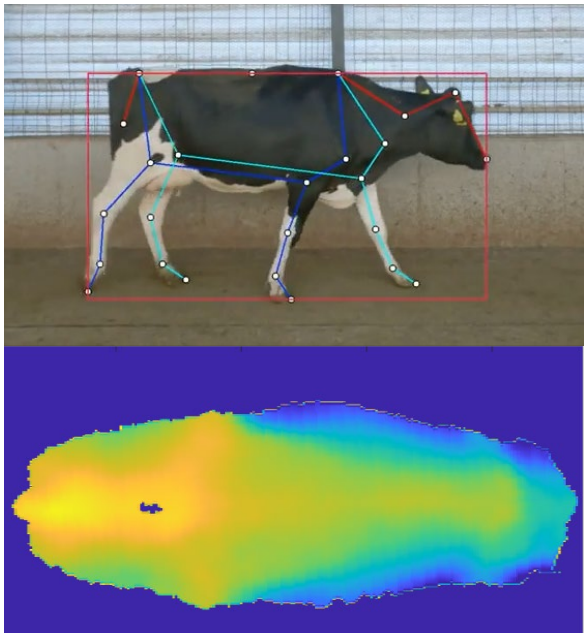
Wearables are defined as electronic devices that can be fitted to animals to monitor their behavior, temperature, and location. These technologies can be fitted "on-animal" such as collars, pedometers, and ear tags or "in-animal" like rumen boluses. Wearables normally utilize accelerometers to detect changes in the vibration and motion of the device and associate them to behaviors such as animal activity levels or the time an animal spends eating or ruminating. Monitoring these behaviors can provide producers with valuable information, as changes in individual behavior have been associated with estrus, calving, and even disease events in dairy cattle. Thus, based on those behavioral changes, producers can make decisions such as breeding, segregating, or treating an animal. In fact, the use of wearable sensors to monitor animal activity for heat detection and animal breeding is a consolidated practice among technology adopters. Furthermore, some of these technologies track the location of each animal. Besides reducing the labor needed to locate an individual animal within a pen or pasture, monitoring animal location allows producers and consultants to assess animal distribution and area utilization. Evaluating animal position and distribution might offer valuable insights that range from resource availability (such as water, feed, and forage) and environmental conditions (such as shade and ventilation) both in pasture and confinement-based production systems. Despite the variety of wearables available and the valuable information they generate, we must acknowledge that fitting and maintaining wearable sensors on every animal can be time consuming and labor intensive.



Examples of wearable sensors including rumen bolus (left), pedometer (center), and collar (right). (Photo: Joao Lovatti)

Cameras:

There are three main types of cameras used in Precision Dairy Farming: RGB cameras (2D images), depth cameras (3D images), and infrared thermal cameras. The main difference between the cameras is the type of sensor they have. RGB (Red Green and Blue) cameras, the same as surveillance cameras, work similarly to the human eye and are equipped with sensors that capture light and translate into a colored image. Depth cameras rely on different range imaging systems (i.e., time-of-flight and stereo vision) that can map the distance between the camera and a certain object and use it to form an image where the pixels represent the object's distance from the camera. Lastly, infrared thermal cameras have sensors that capture the heat radiated by an object and generate an image where the pixel values in the image represent the temperature of the object. The images captured by all these type of cameras can be utilized for a variety of purposes including animal identification, body condition scoring, body weight estimation, lameness detection, and animal behavior and location monitoring. The images from the cameras are processed using computer vision, which is a type of artificial intelligence that translates images into meaningful information. RGB cameras can be utilized to identify individual animals and track their locomotion scores, activity, and feeding behaviors. 3D cameras can be utilized to assess body condition scores in cows and detect variations in body shape that are not easily perceived by the human eye. Infrared cameras can be utilized to monitor animals at night and to record animal temperatures, which can be used for heat stress management or heat detection. In contrast to wearable sensors, the adoption of cameras is a contact-free option to monitor the herd or even individual animals. Furthermore, a single camera is capable of monitoring multiple animals. However, the performance of cameras can be negatively impacted by lighting conditions or when barn structures (i.e. railings and stalls) or animals (i.e. other cows or birds) block the camera view. In addition, capturing and processing images can require high-speed internet connections and more computing power compared to the wearable sensors.



Top image: Use of RGB cameras to record locomotion scores in dairy cows (Photo adapted from Higaki et al., 2024).
Bottom image: Dorsal region of a dairy cow captured by a depth camera with brighter colors representing points that are closer to the sensor (Photo: Rafael Ferreira)

Automated Milking and Calf Feeding Systems:

Automated milking and calf feeding systems are becoming more popular among dairy farmers. These automated systems provide the animals with freedom of choice, reducing possible negative herding interactions between animals and humans. In addition, these systems are also perceived as advantageous not only for removing the need for daily labor-intensive tasks but also for collecting large amounts of data that can aid in animal management. Automated milking systems can record milk yield, milking speed, milk composition, and characteristics (i.e., color and conductivity) and can automatically detect variations in any of those that could be associated with the onset of mastitis or other disorders. Similarly, automated calf feeding systems can record milk intake, drinking speed, and number of visits to the feeder and are also able to automatically identify deviations in those variables alerting the producer of calves under disease risk. In addition, both systems have the option to be integrated with a body weight scale which allows farmers and consultants to track weight gain and losses on cows and calves. This information can be utilized to adjust the milk feeding plan in calves. Still, we must acknowledge that these systems have a few limitations regarding the number of animals that a single system can milk or feed. In addition, implementation of these automated systems can be costly as their installation might require the construction of new facilities or significant changes to pre-existing ones.



Example of a dairy calf utilizing an automated calf feeding system. (Photo: Melissa Cantor)

Adoption and applications of current and novel Precision Dairy Technologies will only increase in the future. Currently, these technologies can individually record and detect deviations in animal performance and behavior that can be associated with the onset of estrus or diseases. However, these technologies are still not able to detect specific diseases or provide producers and consultants with clear and concise management actions based on the deviations observed. Lastly, integrating multiple Precision Dairy Technologies or integrating Precision Dairy Technologies with other farm data recording systems is still a challenge and might pose additional nuances to the establishment of smart farming practices in the future.

Furthermore, we must warn that the adoption of Precision Dairy Technologies will not magically fix all the challenges faced by dairy farmers. Therefore, identifying the challenges and goals of each farm is a fundamental step in determining in which technology to invest in. In addition, the adoption of these types of technologies can reduce manual labor needs but, at the same time, will require producers and consultants to spend more time investing in data analytics and critical thinking skills. Lastly, the current scientific literature demonstrates the economic viability of investing in technologies to improve estrus detection. However, little is known about the true return on investment that these technologies might yield to monitor animal health or be utilized as a strategic tool to improve overall farm management.

This article is the first in a series that will explore how to successfully utilize precision technologies in dairy farming. In future articles we will dive deeper into existing technologies discussing how each technology and its data can be utilized to improve animal and farm management. If you are curious about precision technologies, artificial intelligence, and automation for agricultural and livestock production systems, please visit the Smart Farm Hub at https://smartfarm.cals.wisc.edu There, you will find information on current and upcoming technologies. You can also explore interviews with experts, researchers, and students from around the globe, as well as overviews of current and future research projects.

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