

Dairy Farming 2.0: Milking the Potential of Artificial Intelligence

Diego B. Nobrega

Faculty of Veterinary Medicine, University of Calgary, 3330 Hospital Drive NW Calgary, AB, T2N 4N1. Email: diego.nobrega@ucalgary.ca

■ Take Home Messages

- Farmers considering new artificial intelligence (AI) tools should carefully select solutions tailored to their specific needs.
- Numerous AI tools have emerged to aid in the early detection of prevalent dairy cattle diseases.
- The issue of false-positive alerts poses challenges in AI-based disease detection systems.
- Language models, adept at mimicking human-like text, can be susceptible to sensitive information leakage.
- It is advisable to verify outputs of language models through reliable sources.
- Users are cautioned against asserting ownership of generated text, as it may involve copyrighted content.

■ Introduction

Throughout history, agriculture has undergone many revolutions, from the ancient practice of domesticating animals and plants thousands of years ago to the implementation of innovative farming techniques like crop rotations a few centuries back. We are now seeing another revolution, fuelled by the rapid development and increasing popularity of artificial intelligence (AI). AI tools are becoming more popular among farmers because they behave like high-tech helpers that assist with daily activities on farms. In theory, these tools use technology to monitor how animals behave and detect diseases before they even start. They also help farmers make smart choices for their operations. Imagine having a farm assistant or veterinarian that tells us when animals are getting sick or which cows to breed and when. This assistant, powered by AI and machine learning, is like a digital farm manager making sure everything runs smoothly. However, it is crucial to acknowledge that AI also has many limitations.

This article will introduce farmers to the realm of AI and related concepts in an easily understandable manner. We will delve into some of the most promising applications of AI in dairy farming while also addressing shortcomings of current AI tools.

■ What is AI About? Is it the Same as Machine Learning? What About Precision Dairy Farming?

The concepts of AI, machine learning, and precision farming are interconnected but refer to different aspects. One can think of AI as the brain of a computer system, helping machines to mimic human skills linked to intelligence such as being able to see, understand and respond to spoken or written language, analyze data, etc. Machine learning is like the neurons of this brain, that transmit and process the information, and have the distinctive ability to 'learn' or improve processes the more examples and experiences they receive. Precision dairy farming is a distinct yet interconnected concept that encompasses the use of technology for ongoing monitoring of animals, generating valuable data to guide decision-making

on farms. Machine learning and AI can seamlessly integrate into these systems, tapping on the extensive data generated in the process.

Let's delve into an example that illustrates these concepts. A cutting-edge technology gaining widespread adoption on dairy farms in Canada is the Automated Milking System (AMS), commonly known as robotic milking. Let's imagine a hypothetical AMS built on a set of technologies including robot arms, optical and milk sensors, etc., that collectively oversee and optimize the entire milking process. Keep in mind that robots are not necessarily 'intelligent' robots. Most AMS generate a lot of data, monitoring our animals in real time – a prime example of precision farming. Through the application of machine learning algorithms, our hypothetical AMS could discern patterns and correlations within the data, providing invaluable insights into the health, reproduction, and general well-being of the animals. For example, using machine learning, our system could perform intelligent tasks such as learning to clean teats of varying shapes on the fly, or alerting us to potential mastitis cases, ultimately becoming an artificially intelligent robot. In essence, in this example, our AMS embodies AI systems by executing intelligent tasks that would traditionally necessitate human intervention.

In the example above, we showcased an AMS that could be categorized as artificially intelligent. However, it's important to note that AI tools come in all formats and shapes. They encompass a diverse array of technologies, such as smartphone apps, camera systems, benchtop equipment, milk meters, ear tags, boluses, and more, typically integrated with accompanying computer software.

▪ **As A Farmer, How Should I Approach AI?**

Farmers find themselves amidst a barrage of new AI technologies that promise to revolutionize practices, offering increased efficiency, precision, and productivity. While these advancements hold tremendous potential, a cautious approach is crucial as farmers navigate AI solutions. Farmers face the challenge of selecting the most suitable solutions for their specific needs, considering factors like their farm size, budget, and the compatibility of prospective tools with their existing infrastructure.

One critical consideration is the learning curve associated with adopting these technologies. Dairy farmers may need to invest time and resources in training to fully harness the potential of the AI solutions. Sometimes, farmers will be required to become adept at interpreting the insights generated by these technologies and translating these into action. As a general rule, farmers must consider the number of hours they are expected to put into learning how to operate this new technology, their level of comfort with it, and the estimated gains associated with the technology, and they must think of any potential disruptions to established routines and workflows. Understanding the intricacies of these technologies is essential to ensure optimal integration and prevent potential disruptions to established routines. Transitioning from traditional methods to AI-driven processes may initially pose challenges, and farmers must be prepared to navigate these changes with resilience and adaptability. In many cases, AI providers offer training and ongoing support programs to aid farmers in mastering the functionalities of their tools. Engaging with these resources can facilitate a smoother learning process and enhance the overall effectiveness of the AI solutions. In addition, farmers should approach the integration process with a discerning eye. This involves seeking advice from colleagues making use of this technology and perhaps starting with smaller-scale implementations before committing to extensive changes. Pilot projects can help farmers evaluate the impacts of AI on their operations without exposing the entire farm to potential risks.

A second important consideration is the sustainability and long-term viability of AI tools. Farmers need to assess not only the immediate benefits but also the longevity of these solutions. Concerns about continuous updates, potential obsolescence, and the overall cost-effectiveness of adopting AI systems should be carefully weighed against the expected returns. Given the dynamic nature of technology, regular updates are often necessary to address evolving challenges, enhance functionalities, and stay current with industry standards. Farmers need to be aware of whether AI providers will likely continue in business, providing regular updates to their tools at a reasonable cost. Another problem is that AI tools might become obsolete over time. Consider the following scenario: an AI tool that aids dairy farmers in choosing the correct antimicrobial for therapy during drying-off. Simultaneously, there is an industry-led initiative advocating for a reduction in

antimicrobial use on farms through the adoption of selective dry cow therapy, as well as a pushback in the use of antimicrobial classes that are important to humans. There is a conceivable risk that the tool might become obsolete, particularly if the probability of receiving updates is minimal.

Farmers should also ask AI providers about potential false alerts and how often these occur. Not only do false alarms waste time and effort, but they can also lead to unnecessary interventions causing stress to animals and disrupting established routines. Farmers may lose faith in the technology if they keep getting false alerts, which would make the technology less useful overall. Precision and accuracy in alert systems are very important for farmers to be able to act quickly on real problems, make better decisions, and improve the health of the animals. Finding the right balance between how sensitive AI technologies are to real problems while minimizing false alerts is essential for fostering a successful and beneficial integration of these tools into established routines.

Another consideration is warranted in terms of data privacy and security. AI systems often rely on extensive data inputs, and farmers must ensure that their sensitive information, such as health records and personal data, is adequately protected. Understanding the terms of data ownership and usage in collaboration with AI providers is crucial.

In essence, while the promise of AI technologies in agriculture is immense, farmers should take a cautious approach when adopting new technology, AI-based or not. Below is a list of important questions dairy farmers can make before implementing AI tools in their operations.

- ▶ **Functionality and Purpose:** What specific tasks or challenges on my farm can this AI tool address? Does this tool align with the goals and needs of my dairy operation? Once I receive an alert, what exactly will I do with this information? What is the likelihood that this is a false alert?
- ▶ **Ease of Integration:** How seamlessly can this be integrated into my farm? Is there a potential for disruptions during the implementation process? Are there potential conflicts with other technologies or tools already in use on the farm?
- ▶ **Learning Curve and Training:** What level of training is required for me and my team to effectively use this tool? Are there training resources or support provided?
- ▶ **Over-dependence:** As the system becomes fully operational, to what extent should I depend on it for critical tasks on my farm? What are the potential risks associated with system malfunctions, and in the event of such occurrences, what contingency plans are in place to ensure task completion?
- ▶ **Data Privacy and Security:** How is my farm's data handled and stored? What measures are in place to ensure the privacy and security of sensitive information?
- ▶ **Costs and Budget:** What are the upfront costs associated with adopting and implementing the tool? Are there ongoing fees or subscription costs, and how do they fit into my budget?
- ▶ **Updates and Maintenance:** How frequently does the tool receive updates, and what do these updates typically entail? Is there a clear plan for maintenance, and are there associated costs?
- ▶ **Scalability and Future-Proofing:** Can the AI tool accommodate the potential growth or substantial modifications of my dairy operation?
- ▶ **Support and Customer Service:** What level of customer support is provided by the AI tool provider? Who and how often will customer support be provided? How easy is it to contact the company?
- ▶ **User Feedback and References:** Can the AI tool provider offer references from other dairy farmers who have used the tool? Are there reviews or testimonials available from users in similar contexts?
- ▶ **Compliance and Regulations:** Does this tool adhere to relevant industry regulations and standards?

■ What are Some of the Practical Applications of AI and Machine Learning in the Dairy Industry?

In recent years, there has been a rapid growth of interest in, and applications of, AI to support dairy farms, with an almost exponential increase in the number of studies after 2010. The use of AI in dairy farming is done in tandem with precision farming tools, which consistently generate data from the livestock. The diverse array of contexts in which machine learning and AI tools are being employed for decision-making on dairy farms can be classified in different domains, including physiology and health, animal reproduction, feed intake, and others. We will focus our discussion on a select few machine learning applications that hold promise for on-farm implementation. This overview, while not a complete list of all the ways AI and machine learning can be used on dairy farms, should give farmers a good start on some of the tools that are or will be available to them in the near future.

Physiology and Health

Lameness

Lameness poses a significant health challenge in dairy farming, ranking among the top three reasons for culling cows. Identifying lame cows is crucial for maintaining herd well-being. Lame cows often exhibit an altered walking pattern, characterized by a limp or an uneven gait. They may favour one leg or show reluctance to put weight on a particular hoof. Lame cows also tend to reduce their physical activity, including walking and moving around the barn or pasture. In the pursuit of early detection, scientists have explored innovative approaches such as using machine learning analysis of locomotion data generated by accelerometers (Borghart et al., 2021). This approach demonstrated around 85% accuracy in correctly identifying both lame and normal cows, which is promising, but it is still prone to false positives. In comparison, a machine learning approach using herd health data without the need for accelerometers correctly classified nearly 75% of animals (Warner et al., 2020). Another promising avenue involves leveraging AI for the analysis of video footage to identify lame cows. One study claimed a remarkable 99% accuracy in correctly categorizing cows as 'lame' or 'not lame.' (Wu et al., 2020). However, this publication lacked explicit details on how lameness was diagnosed or defined, which is critical information for accurate interpretation of their results. Hence, while there are potential avenues for the development of automated lameness detection systems based on video footage, one can still not give reliable practical recommendations on the use of this tool based this publication alone.

Digital dermatitis

Digital dermatitis (DD) is a common infectious hoof disease in dairy cattle characterized by painful lesions, primarily affecting the interdigital skin and soft tissues. Recently, a new technology for detecting DD in dairy herds has been developed based on the analysis of videos recorded using security cameras on farms (Cerneq et al., 2020). This approach involves two sets of cameras — one capturing videos of cows' heads to identify animals via ID tags and a second capturing videos of the cows' hooves. These videos are then fed into machine learning models that aim to detect DD lesions and determine the presence or absence of hoof blocks. The system demonstrated an accuracy of 88%, holding promise for the development of real-time DD detection systems on farms through video monitoring.

Mastitis

Considerable research and development efforts have been dedicated to creating AI applications for the early detection of mastitis on dairy farms. These applications are based on the detection of a variety of markers of inflammation, such as changes in color, swelling, temperature or abnormalities in the udder, milk components such as somatic cell count, and historical herd records. Using the udder skin surface temperature recorded using thermal infrared video footages, researchers in China reported nearly 85% accuracy of machine learning models to correctly classify animals as affected by mastitis or not. Similar values were documented by researchers at the University of Calgary using AMS data (Naqvi et al., 2022).

The general consensus seems to be that the predictive power of machine learning models to identify cows with mastitis is high, but not high enough to be implemented in practice because of too many false-positive alerts (De Vries et al., 2023). Indeed, dairy farmers generally prefer a low number of false alerts, emphasizing the importance of high specificity in disease detection systems.

In a related use of machine learning and AI for mastitis diagnostics, a UK research group used data from 1,000 farms to develop an automated mastitis classifier tool (Hyde et al., 2020). This tool analyzes cow and herd data to predict whether a mastitis case is contagious or environmental, an important distinction for effective management and prevention. Contagious mastitis requires targeted measures to isolate and treat affected cows, preventing its spread within the herd. Conversely, environmental mastitis calls for improvements in hygiene and environmental conditions to lower the risk of new infections. Impressively, the machine learning classifier achieved 98% accuracy, offering the potential for farmers to discern mastitis types promptly without waiting for milk culture results.

Another application of AI in mastitis diagnostics is in the interpretation of milk culture results from on-farm mastitis culture systems. A machine learning-powered smartphone application demonstrated comparable proficiency to human experts in interpreting milk culture results for the majority of mastitis-causing organisms (Nery Garcia, unpublished). Interestingly, the accuracy of trained farm staff in reading on-farm milk culture results matched that of the AI algorithm, meaning that the AI application can read culture plates as well as trained personnel on farms.

Heat stress

Heat stress refers to the physiological strain experienced by dairy cows when exposed to excessively high temperatures, especially when coupled with high humidity levels. Cows need a certain temperature range to be able to live comfortably. When temperatures rise above this range, heat stress occurs. The negative impacts of heat stress on dairy cows are substantial, affecting their overall well-being, milk production, reproductive performance, and immune function. Symptoms include increased respiration rates, elevated body temperatures, reduced feed intake, and altered behaviour. Researchers have developed machine learning models to detect animals suffering from heat stress using various data sources including data generated from accelerometers and reticuloruminal boluses (Becker et al., 2021). The accuracy of models ranged from 85 to 89% depending on the cooling system the cows were in (e.g., shades, sprinklers). Overall, the machine learning models demonstrated sufficient accuracy in predicting whether cows were experiencing heat stress or not for most cooling systems. This showcases promising developments in leveraging precision dairy farming tools for early diagnostics of heat stress.

Metabolic diseases

Poor metabolic status elevates the risk of disorders like ketosis and fatty liver in dairy cows. Assessing metabolic status of dairy cows commonly involves blood sampling and analysis, which may disrupt routine practices on farms. Alternatively, milk composition data that is generated monthly in milk recorded herds could potentially be used for identifying cows at risk of metabolic disorders. With this objective, researchers applied machine learning techniques to milk composition data and health records to classify early lactation cows in terms of their metabolic status. A subset of algorithms achieved accurate classification for over 80% of animals, on average, from the first to the seventh week of lactation (Xu et al., 2019).

The performance of machine learning algorithms to identify animals with subacute ruminal acidosis was recently evaluated (Wagner et al., 2020). The approach involved using data from a positioning system, which inferred cow activity based on its position relative to specific locations in the barn (feeder, resting area, and alleys) and train machine learning models to detect behaviours associated with ruminal acidosis. The machine learning models successfully identified 83% of animals experiencing subacute ruminal acidosis. However, there was a notable 66% false positive alert rate, indicating that most alerts triggered by the system were false. This parallels the challenges observed with AMS alerts for mastitis detection, which prevents the adoption of the system in practice.

Animal Reproduction

Machine learning has many applications in the context of animal reproduction. AI-powered systems can analyze data from sensors, wearable devices, or even visual cues to accurately detect signs of heat in cows, indicating the optimal time for insemination. This has been demonstrated recently, where AI-powered systems performed as well as veterinarians to detect cows in estrus based on data from accelerometers and positioning systems (Wang et al., 2022).

While these tools were effective to detect estrus, machine learning predictions of cow conception using health records containing information about parity, breed, measures of genetic merit for fertility, milk production, weight, and longevity for each cow were generally poor (Hempstalk et al., 2015). This tells us that machine learning falls short to predict which cows will become pregnant following insemination, which is not unexpected given the many factors influencing the success of pregnancy establishment post-insemination, many of which are not typically known beforehand.

Machine learning and AI solutions show promise in the domain of calving and dystocia. Machine learning models, trained on calving records, have demonstrated some level of ability to identify cows more prone to calving difficulties. The records encompassed factors such as season, calf sex, breed, previous calving history, parity, and more. While the models proved accurate in flagging potential cases of dystocia, it is noteworthy that the occurrence of false alarms was acknowledged by authors, raising important concerns for practical implementation (Zaborski et al., 2019). For calving, changes in the cow's behaviour have been used for detecting the animal approaching imminent calving. Leveraging data from neck tags and accelerometers, researchers developed machine learning models for identifying cows within 8 hours of calving. The system's positive predictive value, related to its specificity in detecting cows approaching calving, ranged from approximately 60% to 80%. In practical terms, this means that, at best, 20% of the alerts generated by this system would be false alarms.

Feed Intake

Identifying animals that are more efficient can have significant benefits for the dairy industry. Efficient animals are able to convert feed into milk more effectively, maximizing milk production and reducing feed costs for farmers. On the other hand, identifying sick animals through their feed intake can lead to early detection and treatment of diseases, preventing the spread of illness and minimizing economic losses. Therefore, developing systems that accurately measure individual feed intake can be of great value to dairy farmers. On most dairy farms, cows are fed in groups, so it is not easy to get information on how much each cow eats. A research team from Israel developed an automated system for measuring individual cow-level feed intake using cameras connected to a computer. The system relies on monitoring the disappearance of feed in front of the cow, and through machine learning, estimating the amount of feed consumed at each feeding. Although the system is in its early stages of development, it shows promising potential, especially if the data generated can be integrated into models for disease detection. The investigators reported an error rate of less than 200 g per meal, meaning that their system could be used to accurately predict the amount of feed consumed at each meal (Saar et al., 2022).

▪ **What About the Language Models? Are They Safe? How Should I Approach These?**

Language models are AI systems that are programmed to interpret and write text that reads like it was written by a person based on the input that is given in a chat box. These models are trained on huge amounts of text data, which helps them to assimilate language patterns, relationships, and context. They use this information to come up with answers to human queries. Language models can do many natural language processing tasks, such as translating, summarizing, writing code, completing text, and asking questions. ChatGPT is an example of a powerful language model that has been used in a wide range of domains, including agriculture.

Language models can be used as a virtual assistant by farmers seeking real-time knowledge and support.

One can think of it as a super-charged Google search. As an example, a farmer could ask ChatGPT to find out about the best times to feed their cows, get help detecting mastitis in cows, or even to obtain suggestions on how to better manage the milking process. Here is a text output that ChatGPT printed out when asked the following question: “write three sentences about how to best manage clinical mastitis cases on dairy farms caused by contagious bacteria”.

The optimal management of clinical mastitis cases caused by contagious bacteria in dairy cows requires prompt identification of affected individuals through regular udder health monitoring and somatic cell count analysis. Swift isolation of infected cows is essential to prevent the spread of contagious bacteria within the herd. Treatment with appropriate antibiotics, under veterinary guidance, coupled with stringent hygiene practices during milking, contributes to effective control and prevention strategies.

Language models also find applications in academic contexts, exemplified by Scite, a program akin to ChatGPT that attempts to back up its responses with peer-reviewed literature. Because language models are so flexible, they seem like the ideal source of information that has all the answers to all the questions that we could come up with. Farmers could ask specific questions they are interested in and use the output to inform decision-making on farms. However, we must emphasize that these models lack consciousness, personal experiences, or opinions, which clearly demonstrates that these AI systems cannot take responsibility for the generated text or subsequent actions we take based on it. Ultimately, we as humans bear accountability for the content produced by chatbots and actions we take afterwards.

The safety of using language models lies in how they are applied. As a general rule, the following few steps are recommended when using language models:

- ▶ Cross-reference your findings: When seeking information, cross-reference the findings from your queries with trusted sources such as your herd veterinarian, trusted websites, etc. to ensure the accuracy of the information provided.
- ▶ Acknowledge limitations: Language models are pretrained on billions of sentences written in the past. They will likely not have access to the most up-to-date information or capture real-time developments.
- ▶ Do not share sensitive information: Language model chatbots are not good at keeping secrets, or forgetting them. Information entered into these models may be absorbed and potentially made available to others or used for training future models. As a general rule, avoid sharing sensitive information when interacting with language models to ensure privacy.
- ▶ Do not believe what you read: Language models, while excellent at content generation, are susceptible to errors, and the information they provide may not always be backed up by reliable evidence, including platforms like Scite. This happens because of the training process of AI language models. The training data inevitably contains misinformation, and the response generated by these models reflects these inaccuracies.

With these limitations in mind, farmers can utilize language models for various purposes, including the following: 1) Obtain quick information or summaries on agricultural practices, promising new technologies, or market trends.; 2) Edit drafts for emails, reports, articles, or social media posts; 3) Ask questions to enhance your understanding of specific topics or seek explanations for complex concepts in an easy and understandable way; and 4) Brainstorm ideas.

Remember that while language models can be useful, your own experience and knowledge are still the most important things you need to make smart decisions on your farm.

■ What About AI Ethics?

Language models are a subset of AI tools falling under the category of ‘Generative AI.’ These models, including ChatGPT, can create diverse content such as text, audio, video, and code. While the rapid development of generative AI applications is impressive, it brings forth ethical concerns, particularly in the

realm of the so-called deepfakes, which are realistic manipulations of visual and auditory content. One can think of deepfakes as a modern version of Photoshop that not only can edit photos, videos, and voices, but also create content using only a handful of previous data. The technology allows any individual, regardless of their level of ability with computers, to create videos, photos or voice that look real.

Specifically on language models, dairy farmers should be mindful of two ethical concerns. The first revolves around sensitive information disclosure. Users might inadvertently expose confidential data, such as legal contracts or personal information, to the model, potentially becoming part of the training dataset and available for future users. This poses a significant risk to data security and privacy.

The second ethical consideration relates to intellectual property (IP). As language models do not have the capacity to own copyright, users may feel tempted to claim ownership of the text output. Yet, claiming ownership of text generated by these models raises complex questions. Language models are trained on existing content, some of which may be copyrighted, potentially leading to unintentional infringement when users claim ownership of AI-generated text. As a general rule, users should refrain from claiming ownership of the generated text. In case of doubt, seeking advice from IP experts is the recommended course of action. The legal landscape regarding ownership of AI-generated content is not definitively settled, and ongoing developments may shape the future of these ethical considerations.

▪ Summary

Artificial intelligence, or AI, encompasses machines that are programmed to act like humans and perform tasks typically associated with human minds. It is likely that these tools will make things easier for managing dairy herds, especially finding diseases early on. Farmers are increasingly exposed to a variety of new tools and should identify the best solutions for their needs. As commonly done before implementing any new technology, farmers should be cautious and think about things like the size of their farm, their budget, infrastructure, learning curve, and the privacy and security of their data before adopting new tools.

In the past few years, AI tools have been developed to detect common diseases of dairy cows, such as lameness, digital dermatitis, mastitis, ketosis, and acidosis. These tools are used with precision farming tools, which constantly gather information from the animals. Farmers should also pay close attention to the number of false-positive alerts that may disrupt routines and cause actions that were not needed.

Language models are AI systems that are designed to read and write text that looks like it was written by a person. Farmers can use them as virtual assistants to get real-time information. These models cannot be held accountable for the text they create or the things we do after reading it. How they are used determines how safe they are. As a general rule, users should avoid sharing sensitive information with these systems, and double check the output using trusted sources. Users should also not claim ownership of the text that is created, as some of it may be protected by copyright.

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