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Machine learning tools in animal nutrition

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ABSTRACT

Machine learning is a subset of artificial intelligence, which is defined as "the science and engineering of making intelligent machines." By providing creative ways to improve livestock productivity and health, artificial intelligence (AI) and machine learning (ML) are rapidly changing the animal nutrition industry. By analyzing large datasets from multiple sources, including as environmental factors, genetic data, and feeding experiments, these technologies make it possible to create more accurate nutritional formulations that are suited to the requirements of specific animals. Researchers can maximize nutrient uptake, minimize feed waste, and raise livestock's total feed efficiency by utilizing predictive modelling and data-driven insights. Machine learning can help to predict methane production in livestock and then use that information to manipulate feed composition to mitigate methane emissions. As these technologies continue to evolve, their application in animal nutrition holds promise for significant advancements in improving feed utilization, strategies for reducing feed wastage leading to animal welfare and sustainable development.

Keywords: Algorithms, Data analysis, Machine learning, Supervised machine learning

Introduction

With new technology spurring innovation across multiple industries, artificial intelligence (AI) is a field that is always changing. AI is "the science and engineering of making intelligent machines" (McCarthy, 2002) or intelligent computer programs, according to John McCarthy, the father of artificial intelligence. AI gives machines the ability to reason without human assistance. Arthur Samuel defined machine learning as the field that enables computers to learn without explicit programming. He gained fame for developing a checkers-playing program. Machine learning (ML) equips machines to process data more effectively. When humans struggle to derive insights from data after reviewing it, ML steps in to help. With vast datasets now readily available, demand for ML continues to surge. Industries across sectors leverage it to pull out key information. Ultimately, ML's goal is to enable learning directly from data. Researchers have long explored ways to make machines self-learn without hard-coded instructions.

Machine learning draws on various algorithms to tackle data challenges. Data scientists emphasize that no universal "best" algorithm exists for every problem. The choice of algorithm hinges on factors like the problem type, number of variables, and the most suitable model. Mathematicians and programmers employ diverse techniques to tackle challenges involving massive datasets.

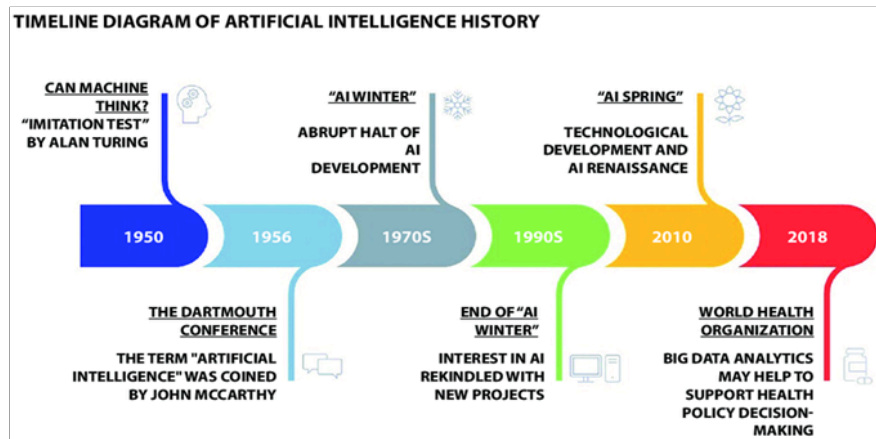
This may entail a number of tasks, including: Reasoning: Examine data and make sense of it all. Learning: Use data to gain new abilities and understanding. Solving problems: Determine issues and find solutions in a methodical manner. Making decisions involves weighing your options and selecting one based on the information at hand.

History: Types of AI:

1. **Artificial Narrow Intelligence (ANI):** Artificial Narrow Intelligence refers to AI systems that are designed to perform specific tasks or functions with a high level of proficiency.
2. **Artificial General Intelligence (AGI):** Artificial General Intelligence refers to AI systems that possess human-level cognitive abilities across various domains.
3. **Artificial Super Intelligence (ASI):** Artificial Super Intelligence refers to AI systems that surpass human intelligence in virtually every aspect. ASI is an advanced form of AI that would possess cognitive abilities far beyond what any human mind can comprehend.

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Subtypes of artificial intelligence

AI encompasses several subtypes, including machine learning (ML), computer vision (CV), fuzzy logic (FL), and natural language processing (NLP). ML relies on algorithms that learn decision-making patterns from analyzed data and are categorized by the feedback they receive. Supervised learning uses pre-labeled data as input. Unsupervised learning, by contrast, works with unlabeled data, requiring the system to identify and group similar patterns. Semi-supervised learning blends both, processing a mix of labeled and unlabeled data. Reinforcement learning evolves through trial and error, adapting from successes and failures. Deep learning (DL), a ML subset, employs artificial neural networks (ANNs) with multiple layers to mimic human brain processing. It features layered hidden nodes that progressively abstract data representations.

CV enables computers to analyze images, identify elements, and assign meaning to them. FL handles non-binary values to address problems beyond traditional logic's scope. NLP focuses on enabling machines to comprehend and interact using human language (Bellini *et al.*, 2022) [1].

Machine learning, which use statistical techniques to allow machines to learn from experience, is our area of interest. A subset of machine learning called deep learning makes it possible to compute multi-layer neural networks. There are multiple layers in a deep neural network, including input, hidden, and output layers. Through a sequence of nonlinear transformations, each neuron in these layers modifies the input data, enabling the network to learn complex data representations.

Machine learning

According to Samuel machine learning (ML) is the field of study that enables computers to learn without explicit programming. Instead of depending just on pre-programmed rules, the definition highlighted how machines may learn from data to improve their performance, make predictions, or solve problems. Machines can be trained to han-

dle data more effectively through the application of machine learning (ML).

Traditional programming vs ML

Traditional programming is manual process where programmer has to manually

Create rules and logic that determine how a program will process input to produce specific output.

ML process is automatic, from input and output data the machine automatically formulate rule.

This approach is particularly useful for complex problems where defining explicit rules is difficult or impossible.

Giving computers the ability of learning rules from the past experiences without being explicitly programmed (Samuel, 1959) [2].

Types of machine learning

Three types of machine learning supervised machine learning, unsupervised machine learning and reinforcement machine learning

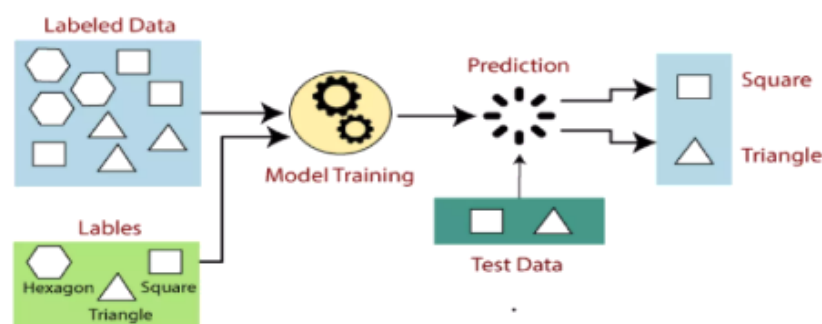
- Supervised machine learning: Machine is train using well labeled training data and on the basis of data machine predict the output, whatever data we collect divide into training data and test data. With the help of training data we train the model and using test data we evaluate the model to access the accuracy of trained data. Needs an external assistance.

For example,

Consider the input dataset as triangle hexagon and square image initially, the machine is trained to understand the image. Post-training, an input picture of a triangle is provided, and the machine is expected to identify the object and predict the output. This is the process of object identification in supervised machine learning.

- Unsupervised machine learning: Machine is trained without label. Algorithm find pattern in the data and partition them based on similarity. There is no correct answer and teacher

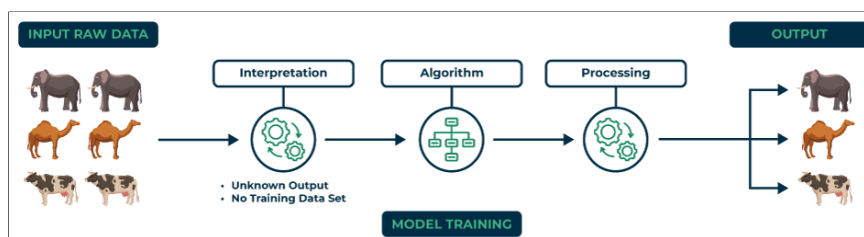
For example,



Consider an input dataset of images of a different animal. Here, the images are not known to the machine learning model. When we input

the dataset into the ML model, the task of the model is to identify the pattern of animal, such as colour, shape, or differences seen in the in

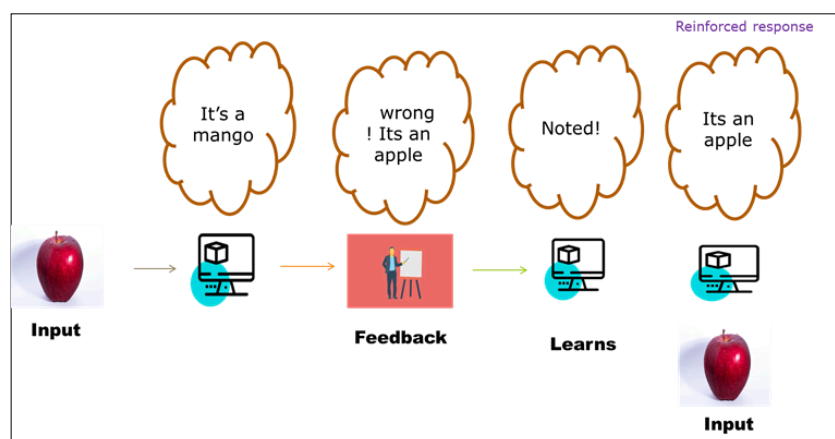
put images and categorize them. Upon categorization, the machine then predicts the output as it gets tested with a test dataset



- c. Reinforcement machine learning: Is feedback based process. Dynamic training method where machine learn to make decision by interacting with environment. Machine receives feedback through reward and penalties based on its action guiding its learning process over time. The component / machine is rewarded for each good action and penalized for every wrong move. Thus, the reinforcement learning component aims to maximize the rewards by performing good actions.

For example,

Consider input dataset is apple and machine gives a response it as a mango, we gave a feedback to machine that its answer is wrong and correct answer is apple. machine will note it down and in future if same data came across machine will give a correct response. It is one of the trial and error learning.



Commonly used ML algorithm

1. Linear regression: Is supervised ML utilized to predict numerical outcomes by modeling the relationship between a dependent variable and one or more independent variable.
Limitation: Linear regression assumes a linear relationship between dependent and independent variable. Real-world relationships might be non-linear, leading to inaccurate predictions.
2. Random forest: Random Forest is a popular supervised machine learning algorithm that is widely used for both classification and regression tasks.
RF can efficiently handle larger datasets.
3. Support vector machine: Support Vector Machines (SVMs) are powerful supervised machine learning algorithms primarily utilized for classification and regression tasks. SVM exhibit higher computational complexity compared to random forest when dealing with large dataset.
4. Extreme learning machine: Classification, regression, function approximation, pattern recognition, forecasting and diagnosis. ELMs demonstrate a notable ability to generalize well from training data. ELMs require less human intervention compared to other machine learning algorithms.
5. Real genetic code algorithm: Most of real-world multi-objective optimization problems. Ability to perform well on problems that require continuous optimization (making best choice).

A. Feed formulation

This approach utilizes various data sources, including:

- Animal sensors: Track vital signs like temperature, heart rate, and activity levels, providing insights into individual animal health and well-being.
- Feed sensors: Analyze the nutrient composition of feedstuffs in real-time, ensuring accurate nutritional intake.
- Milk analysis: Monitor milk quality and composition, revealing potential nutritional deficiencies or imbalances.

By analyzing this data through machine learning algorithms, AI systems can create personalized feeding plans for each cow. These plans consider the animal's unique needs based on factors like breed, age, stage of lactation, and individual health status.

B. Prediction of diet energy digestion

In order to effectively evaluate the diet nutritional and feeding value, it is essential to accurately predict the indicators of diet energy digestion of dairy cows, thus further optimizing feed formulation and improving feeding management.

In general, there are many indicators for evaluating the diet energy digestion and utilization of dairy cows, including gross energy (GE), digestible energy (DE), metabolizable energy (ME), net energy (NE), energy digestibility (ED) and energy metabolizability (EM)

A case study with Holstein dry cow [Fu et al., \(2020\)](#) ^[3]

Traditional method: linear regression equation (parameteric model)

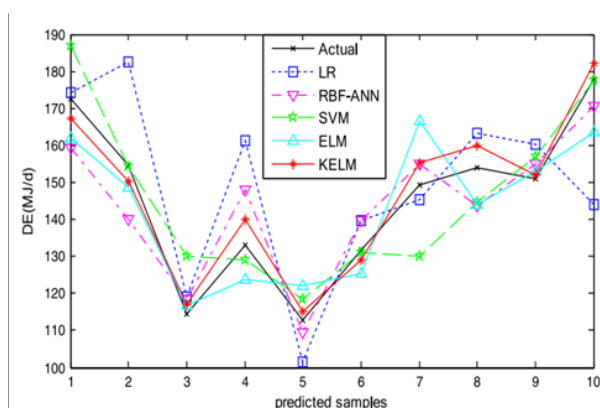
Machine learning model: kernel extreme learning machine (non parameteric)

livestock	models	Application
Dairy cattle during pregnancy	Real-coded genetic algorithm	The use of a real-coded genetic algorithm (RGA) to find least-cost feedstuffs without any nutrient deficiency Kuntal <i>et al.</i> , 2016
Dairy and beef Cattle	Multi-objective optimization algorithm	An evolutionary algorithm minimizes feed cost and deviation from the specified requirements. Uyeh, <i>et al.</i> , 2019
Poultry	Linear programming algorithm	The use of linear programming technique in the minimization of cost in a small-scale poultry farm. Mallick <i>et al.</i> , 2020

Animal: 3x3

Age : 45 ± 3 months

Body weight: 560 ± 20



Artificial neural network (ANN),

Support vector machine (SVM)

Extreme learning machine (ELM)

Linear regression (LR)

Kernel extreme learning machine (KELM)

Figure. Results obtained by different methods for DE prediction

Result: The prediction accuracy metrics of the other three comparison methods such as RBF-ANN, SVM and ELM are relatively close, and their main metrics values are better than those of the LR-based method, but inferior to those of the KELM-based method.

C. Automated system to monitor enteric methane and co2 emission (Hristo *et al.*, 2015) [4]

Enteric CH₄ is the largest contributor to GHG emissions from livestock. Therefore, animal scientists have focused their research on discovering mitigation technologies for reducing enteric CH₄ production from ruminants. Techniques for measuring enteric CH₄ vary from direct measurements (respiration chambers, which are highly accurate, but with limited applicability) to various indirect methods (sniffers, laser technology, which are practical, but with variable accuracy).

The sulfur hexafluoride (SF₆) tracer gas method is commonly used to measure enteric CH₄ production by animal scientists and more recently, application of an Automated Head-Chamber System (AHCS). AHCS is an automated system to monitor CH₄ and carbon dioxide (CO₂) mass fluxes from the breath of ruminant animals respiration chambers are considered the “gold standard” for measuring rumen gas emissions, their major disadvantage is that the number of animals on trial is usually limited due to the limited number of chambers available at a particular research facility

Both the SF₆ technique and AHCS enable emissions to be analyzed on a large number of animals in free grazing conditions or in free- and tie-stall barns. Methane production in the rumen is a substrate-dependent microbiological process. Production of CH₄ and CO₂ increases after the animal is fed and decreases thereafter.

Results of study: A study with growing dairy heifers concluded that AHCS was capable of estimating CH₄ emissions from livestock and

emission estimates generated by AHCS were comparable to values obtained by respiration chamber.

It was concluded that CH₄ emissions measured by the AHCS were similar to literature values derived from respiration chambers and between animal variability (CV of 11 to 12%; repeatability of 0.64 to 0.81) was also within the range reported for respiration chambers

The advantages of AHCS over respiration chambers:

- The animal is not restricted and is in its natural environment (i.e., on pasture),
- Can freely move (in a free-stall barn)
- AHCS is also less expensive to build than a traditional respiration chamber.
- This relatively low cost is important, particularly for CH₄ mitigation research in developing countries

The advantages of AHCS over the SF₆ tracer method,:

- AHCS is simpler to operate
- Does not require complicated and expensive analytical equipment

Measuring CH₄ production in the rumen are critically important for the success of GHG mitigation efforts. AHCS is an automated gas measurement system that has been proven to deliver reliable and accurate estimates of enteric CH₄ and CO₂ emissions from beef and dairy cattle

Advantage of machine learning

- Estimate the relationship between different variable.
- The machine is able to adapt to change easily.
- Machine learning methods reveal concealed relationships and links through a large data stack.
- Saves time and effort that would otherwise be spent on programming and increases adaptability to solve various problems.
- ML algorithms can be applied to different problems, perform different tasks.

Limitation of machine learning

- The algorithms often deal with large volumes of big data that can contain missing values, outliers, and unwanted data points, which can lead to inaccurate predictions and unreliable outcomes.
- All the activity carried out in the farms are not fully automated, and hence data may not be properly annotated and may be lost and/or inaccurate.
- High Computational Resource Requirements
- Many machine learning models, can be highly complex and difficult to interpret.
- Machine learning models can suffer from issues like overfitting, where the model performs well on training data but fails to generalize to new, unknown data, or underfitting, where the model is too simple to capture the underlying patterns in the data.
- High cost

- The best learning algorithm for a particular data set, does not guarantee the precision and accuracy for another set of data whose attributes are logically different from the other

Future prospectus

- Advancing On-Farm Methane Emission Monitoring Technologies
- Advancements in AI-powered automated feeding systems and precision nutrition
- Integrating advanced technologies, including IoT, robotics, and edge computing
- Continuous Innovation and Research - A reference guide for potential research and applications for both academia and industry professionals as well as for decision-makers, from a technical point of view.

Conclusion

- Machine learning is a field of study associated with artificial intelligence which is based on extracting information and learning from data.
- A successful machine learning model depends on both the data and the performance of the learning algorithms.
- ML classification requires thorough fine tuning of the parameters and at the same time sizeable number of instances for the data set.
- Machine learning algorithms represent a significant advancement in animal nutrition, offering opportunities to optimize feeding practices, improve health outcomes, and enhance overall efficiency in agricultural practices.
- Continued research and application will likely lead to further innovations in this field, potentially transforming how we manage and understand animal nutrition in the future

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