Machine Learning & Mathematical Modeling

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Abstract

Exploring the junction between conventional mathematical modelling methods and state-of-the-art machine learning algorithms has garnered more attention in the last few years. In order to provide more reliable and accurate predictive models, this study looks into how these two areas can work together.

1 Introduction

1.1 Background

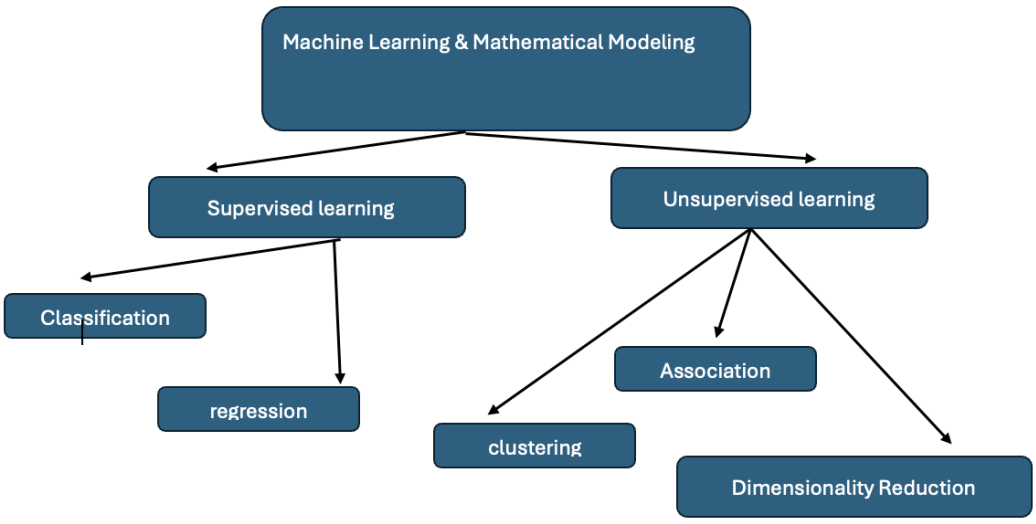

Figure 1: Classification of Mathematical modeling & Machine learning

Supervised and unsupervised learning are core components of building a machine learning mathematical model. Supervised learning uses label inputs and outputs data, while unsupervised learning model doesn't.

In Supervised learning, the machine learning algorithm is trained on a labeled dataset. The algorithm knows what the correct output is in each example of the training dataset. Algorithm uses this knowledge to try to generalize to new examples that its never seen before. Using labeled inputs and outputs the model can measure its accuracy and learn overtime. Supervised learning can be actually divided into a couple of subcategories such as classification and regression.

Classification determines whether the output is a discrete class label such as spam and not spam. linear classifiers , support vector machines, SPM, decision trees , random forests are common examples of classification algorithm. Regression determines whether the output is a continuous value such as price or probability. linear regression and logistic regression are two common types of regression algorithms.

Unsupervised learning is where the machine learning algorithms is not really given any labels at all. These algorithm discover hidden patterns in data without the need for human intervention. Unsupervised learning is used for three main tasks, such as clustering , association and dimensionality reduction.

Clustering is where the algorithm groups similar experience together. Common application of clustering is customer segmentation where businesses might group customer together based on similarities like age, location or spending habits. Association is where the algorithm looks for relationship between variables in the data. It is often used in market basket analysis where business want to know which item are often bought together. For instance, customer who bought this item also bought this sort of things. Dimensionality reduction algorithm reduces the number of variables in the data while still preserving as much of the information as possible. This technique is used in pre-processing data storage when autoencoders remove noise from visual images to improve picture quality.

2 Methodology

2.1 Neural network-based deep learning approach

A neural network-based deep learning approach is a powerful technique used in machine learning for solving complex problems by learning representations of data through multiple layers of abstraction. Deep learning architectures, particularly neural networks with many hidden layers, have demonstrated remarkable success in various domains such as image recognition, natural language processing, and speech recognition.

Here's an overview of the components and key concepts of a neural network-based deep learning approach:

1. Neural Network Architecture:

    - Neural networks consist of interconnected nodes organized into layers. The three main types of layers are input layers, hidden layers, and output layers.
    - Deep learning typically involves neural networks with many hidden layers, enabling the model to learn complex hierarchical representations of the input

data.

- Each node in a layer is associated with a weight and bias, which are adjusted during training to minimize prediction errors.

2. Activation Functions:

   - Activation functions introduce non-linearity into the neural network, allowing it to learn complex relationships in the data.
   - Common activation functions include sigmoid, tanh, ReLU (Rectified Linear Unit), and softmax.

3. Training Process:

   - Deep learning models are trained using large datasets through a process called backpropagation.
   - Backpropagation involves iteratively updating the weights and biases of the neural network to minimize the difference between the predicted outputs and the actual outputs.
   - Training typically involves optimizing a loss function using optimization algorithms such as stochastic gradient descent (SGD) or Adam.

4. Convolutional Neural Networks (CNNs):

   - CNNs are a specialized type of neural network designed for processing grid-like data, such as images.
   - CNNs use convolutional layers to learn spatial hierarchies of features in the input data, enabling them to capture patterns and structures at different scales.

5. Recurrent Neural Networks (RNNs):

   - RNNs are another type of neural network architecture designed for sequential data, such as time series or text data.
   - RNNs maintain an internal state or memory, allowing them to capture dependencies and context over time.
   - Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) are popular variants of RNNs that address the vanishing gradient problem.

6. Applications:
   Deep learning has been applied to various domains, including computer vision (image recognition, object detection), natural language processing (language translation, sentiment analysis), speech recognition, healthcare (diagnosis, drug discovery), finance (fraud detection, algorithmic trading), and many more.

In summary, a neural network-based deep learning approach leverages the power of deep neural networks to automatically learn hierarchical representations of complex data, leading to state-of-the-art performance in various tasks across different domains.

3 Analysis

In supervised learning the algorithms learns from training datasets by iteratively making predictions on the data and adjusting for the correct answer. It tends to be more accurate than unsupervised learning models. Unsupervised learning require upfront human intervention to label the data appropriately. For example, a supervised learning model can predict how long your commute will be on the time of the day and based on the weather conditions. But you have to train it to know things like rainy weather extends the driving time.

By contrast, unspervised learning models work on their own to discover the inherent structure of unlabeled data. These models don't need humans to intervene. They can automatically find pattterns in data and group them together. Unsupervised learning model can cluster images by the objects they contain like people, animals and buildings without being told what those objects were ahead of time. An important distinction to make is that unsupervised learning models don't make predicitons, they only group data together. If you use an unsupervised learning model on that same commute dataset, it would group together commutes with similar conditions like the time of the day and the weather. But it wouldn't be able to predict how long each commute would take.

4 Conclusion

In which of the option of supervised learning and unspervised learning is right for you? In general, supervised learning is more commonly used than unsupervised learning and that's really because it's more accurate and efficient. But that being said, unsupervised learning has its own advantage.

Firstly unsupervised learning can be used on data that is not labeled, which is often the case in the real world datasets. Secondly , unsupervised learning can be used to find hidden patterns in data that supervised learning models just wouldn't find. Classifying big data can be a real challenge in supervised learning , but the results are highly accurate and trustworthy. In contrast unsupervised learning can handle large volume of data in real time. But there's a lack of transparency into how that data is clustered and a high risk of accurate results.

But it is not either or choice, you could do semi supervising learning where you use a training data set with both labeled and unlabeled data. It is particularly useful when its difficult to extract relevant features from data when you have a high volume of data. For instance, you could use a semi supervised learning algorithm on a dataset with millions of images where only a few thousand of those images are actually labeled. Semi supervised learning is ideal for medical images, where a small amount of training data could lead to a significant improvement in accuracy. For example, a radiologist can look at and label some small subset of CT scan for tumors or diseases. Then the machine can more accurately predict which patients might require more medical attention without going through and labeling the entire set.

Machine learning models are a powerful way to gain the data insights that improve

our world. The right model for your data depends on the type of data that you have and what you want to do with it?

5 Acknowledgement

OpenAI. (2022). ChatGPT [Software]. Available from https://www.openai.com/chatgpt