Chapter 9
A Scoping Review of Current Developments in the Field of Machine Learning and Artificial Intelligence

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ABSTRACT

This chapter gives a broad outline of machine learning and artificial intelligence, and introduces the reader to many novel and latest developments in the field of machine learning. The first half of this compilation provides a comprehensive view of the classical concepts of machine learning. Subsequently, examples of machine learning frameworks are discussed. Deep learning, concepts, models, types, and algorithms in machine learning are elaborated in the subsequent section, followed by a detailed introduction to neural networks, concepts of weights, propagation, and initialization. The final section of this chapter introduces the reader to the fascinating and latest world of cutting-edge applications of machine learning like convolutional neural networks (CNNs), bidirectional long short-term memory (BLSTM), artistic, image-generating AI engines like DALL-E and stable diffusion, music and drama writing AI engines, human-like chatbot ChatGPT, art generation with AI, generative neural network concepts, regenerative neural network, and natural language processing (NLP).

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INTRODUCTION

Machine learning (ML) is the process of learning meaningful patterns from a given complex data and produce meaningful predictions about the data found in the real-life situation with minimal human involvement. The term was coined by Arthur Samuel in 1959. Like all human experiences, like playing football, the ability of computer to learn improves with experience or training. The data that is used to train or teach the computer is called the "training set". The most common example of ML is the spam filter that filters junk mail from genuine ones that arrive daily at our inbox. Another common example of ML is heuristics, used in the antivirus program that differentiates a virus program from a genuine one. Yet, another example is the personalized suggestions given on sites like Google or Amazon. These ML prediction on our liking, are based on data harvested from our browsing or shopping habits. A set or collection of data is called a dataset (Watters, 2021).

ENSEMBLE LEARNING

Ensemble learning is an advanced machine learning technique utilized to improve the predictive accuracy of a model by combining the predictions from multiple individual models. By training multiple models with different supervised (regression and classification) algorithms, ensemble learning leverages aggregated insights from different classifiers or regressors for enhanced predictive power. This highly versatile strategy functions well for complex real-world problems as it narrows down uncertainties in prediction tasks due to its ability to capture cross-model correlations across data sets. Furthermore, through intuitively deciding which models are good candidates for data extraction based on their overall performance, ensemble learning can help reduce overfitting and the need for substantial amounts of training data (Sullivan, 2017).

BIG DATA

"Big data" means that large datasets that are usually, automatically generated and that cannot be processed using traditional data management software like Microsoft Excel or Access. This term was popularized by John Mashey in 1900s. Essentially, parallel computation and large storage media are needed to process big data. Special software like Apache Hadoop, Java based Hive, Cloudera, MemSQL, Apache Spark, Amazon S3 can handle the volume of big data. This is due to the sheer size of the data produced, that storage and manipulation is cumbersome. For example, it is estimated that Google processes about 15 Exabyte of data per day. It is staggering to note that 15 Exabyte is equal to 15,000,000,000 (109) Gigabytes, for comparison consider a standard pen drive has 64 Gigabyte of data storage capacity, and a large hard disk has an average capacity of 1 terabyte, 15 Exabyte of data would need around 15,000,000 hard disks. Interestingly, it is estimated that only 0.5% of generated data is used for some form of data analysis(Ankur Saxena et al., 2021).

It is amazing to note that within the span of a minute, 575,000 tweets are posted, 240,000 photos are shared on Facebook, 694,000 hours of video are streamed on the YouTube, 5.7 million searches are conducted on Google search, 283,000$ worth of shopping is done by customers on Amazon, and 856 minutes of webinar are hosted on Zoom meeting platform. Such vast quantity of data is processed online per minute (Fontichiaro, 2018).

Distributed File Systems (DFS) are used to store big data where large data is divided into chunks, which are the stored in pieces across multiple devices or nodes connected by a network. Examples are MongoDB, Apache Cassandra, and ElasticSearch, Apache Spark, Apache Hadoop, and Amazon S3 (based on Amazon Web Service).

Big data can be curated and vetted structured data, or it can be raw, dirty unstructured data. This data can in form of various data types like numbers, images, text, audio-files, and videos. Data can be structured or unstructured. Structured data, curated and annotated Number, Dates and String, constitute only about 20% of big data. These can be processed by Relational database like SQL. Unstructured data image, audio, video, excel sheets, emails, word documents, constitutes a major fraction of about 80% of big data. These cannot be directly processed by Relational database like SQL and need cleansing, conversion, and pre-processing.

This differentiation is important as different ML strategies are needed to evaluate different data types like for example, numerical data is modelled in ML using mathematical linear regression and image classification is achieved using mathematical logistic regression (which produces binary True or False outputs). Typical examples of big data sources are from diverse fields like Physics -Computational ñuid dynamics (CFD) data or Particle physics - Large Hadron Collider data, Bioinformatics - human genome project, Climatology – NASA's Climate Simulation, Astronomy- Event horizon telescope or Sloan Digital Sky Survey (SDSS) and Business – Walmart or Amazon (Dinov & Springerlink, 2018)(Bari et al., 2017).

Such large volume of data can be used to analyze using ML and solve problems which could not be possible with smaller datasets. There are five "V" associated with big datasets, namely: volume (bulky datasets), variety (structured, unstructured, numeric, videos and all kinds of data), velocity (fast speed of build-up of data, using high speed internet connection), value (usefulness of data) and veracity (truthfulness of data). ML aims to classify or derive meaning of this big data (Bari et al., 2017).

PREDICTIVE DATA ANALYTICS

Predictive data analytics is a highly effective tool to enable organizations to gain deeper insights into the behaviour of their customers, operations, and systems. By leveraging predictive algorithms and machine learning techniques, companies can uncover patterns in their data that can be used to inform future decisions, improve operational efficiency, and reduce cost. Predictive analytics also helps companies identify potential risks and opportunities, enabling them to make well-informed strategic decisions based on comprehensive analysis of historical data. Through predictive analytics, companies can improve customer experience, segment valuable customer segments for targeted marketing campaigns and monitor business performance over time with greater accuracy (Antoniou et al., 2019).

BLOCKCHAIN TECHNOLOGY

Blockchain technology is a revolutionary network revolutionizing how businesses process, store, and protect sensitive data. The distributed ledger technology allows computers on a decentralized network to digitally store, update, and share ledgers of transactions in real-time, increasing security and transparency. Additionally, because of its design blockchain also makes it nearly impossible for hackers to intercept or alter data stored on the network since each new block is cryptographically secured to the previous block as well as being processed by a consensus mechanism that requires different nodes to agree before any changes take place. This means that users can trust that any transaction they authorize are accurate and secure from tampering or malicious attacks without the need for an intermediate third-party.

Blockchain technology is a powerful network that stores and records digital transactions in a decentralized database that is secure by design. The blockchain, also known as distributed ledger technology, allows all parties involved in the network to securely access records of past activities on the network. A key advantage of blockchain networks is that they are almost impossible to tamper with and the data stored on them can’t be altered or deleted without leaving a traceable record of all past transactions and activity. As such, this provides unparalleled levels of security and data transparency for users and businesses alike. Ultimately, blockchain networks provide increased trust between contributors as well as improved privacy, scalability, cost efficiency, and authentication for commercial services (Isaacs, 2017).

ARTIFICIAL INTELLIGENCE

Artificial intelligence is a term coined by John McCarthy in 1956 at the first ever AI conference held at Dartmouth College, Hanover, USA. Depending on autonomy of the AI, it is classified into 2 types: weak AI and strong AI.

Weak AI—also called narrow AI is training of computer to perform a single, specific task like driving a car (CV), predicting a mileage of a car (Linear regression), chatbots/ virtual agents (NLP), Google translate (NLP), Amazon's Alexa (ASR), classifying an X-Ray (Logistic regression), identifying a tumour on CT scan (CV). This is the current level of development of AI(Pearce, 2011).

Strong AI - is making the machine think and behave like a human being, including self-awareness, learning, planning, and improvising. This level of autonomy of AI will be reached in the coming decades(Pearce, 2011).

MACHINE LEARNING

Machine learning is a sophisticated form of artificial intelligence consisting of algorithms that can learn from data and improve their performance over time. It focuses on the development of algorithms used to find patterns in large datasets, then use those patterns to make predictions about future events or outcomes. Through this technology, businesses can automate decision-making processes and increase operational efficiency by utilizing predictive analytics such as customer segmentation, fraud detection, risk management, and recommendation systems. Machine learning can also be utilized for natural language processing applications like voice recognition and text translation. This technology has helped organizations save both time and money by leveraging ever-growing amounts of data so that organizations can benefit from it quickly and efficiently (Sullivan, 2017).

DEEP LEARNING

Deep learning is a type of machine learning that has been used in AI that is a subset of ML, which can input unstructured data and automatically determine the feature set based on the provided dataset(Goodfellow et al., 2016). Features are generally determined by human intervention in conventional ML by observation and interpretation of the dataset. It is an algorithm that learns to do things by processing data and information. Deep learning algorithms are trained with large amounts of data, like pictures, voice clips and text documents (Sejnowski, 2018).

The applications of deep learning are vast, and it can be used in many different fields. In the future it will be able to help with medical diagnosis, self-driving cars, natural language processing, speech recognition and more. Deep learning achieves this feat by using what is called a Neural Network as shown in the figure below (Dargan et al., 2019).

Types of Learning in ML

Supervised learning or Discriminative ML is ML from curated datasets, in which features determined by human speculation of the datasets. Some paradigms in supervised ML are as follows: neural networks, k Nearest Neighbours, linear regression, decision trees, logistic regression, random forest, Naïve Bayesian ML, support vector machine (SVM), Convolutional Neural Network, Boosting algorithms (XGBoost, Gradient Boosting Machine, and Light GBM) and Neural networks (Watters, 2021).

Naïve Bayesian ML, which uses a Markov chain to compute Posterior distribution in a manner of classical Naïve Bayesian reasoning. This is a specific useful algorithm for smaller datasets where the conventional ML fail due to lack of sufficient learning data. Naïve Bayesian ML is thus especially suited for implementing ML on memory limited Android mobile phones. In addition, Naïve Bayesian ML provides insight into the inner working of the underlying model which is essential in fields like healthcare research (effectiveness of a lifesaving drug or survival after a cancer) (Watters, 2021).

Unsupervised learning or Generative ML is learning from unstructured datasets, where patterns are captured as probability densities. The various algorithms used for Unsupervised ML are as follows: K-means clustering, Principal Component Analysis (PCA), Singular Value Decompose (SVD), Boltzmann machine, Auto encoder, Recurrent Neural Network and Sum Product Network. Hierarchical Clustering, and Neural networks are some examples of Unsupervised ML methodologies. A common example of Unsupervised learning ML are product recommendations offered on Amazon site, which are generated using Clustering methodology, predictions based on data of user's shopping habit. A Hybrid ML also exist for example, Deep Neural Network (Watters, 2021).

CONCEPT OF A MODEL IN MACHINE LEARNING (M.L)

A machine learning model is a program that has been trained using training dataset, has achieved a defined accuracy, having learnt to recognize patterns in data and predict or classify data in the test dataset or unseen dataset. As an example, consider the game of chess. In this game, there are more possible moves than there are atoms in the universe. A computer cannot play Chess well because it cannot look ahead and see all the possible moves. However, if we feed a computer with enough data about past games of chess and allow it to learn from them, then it will be able to play Chess at a reasonable level. Machine learning algorithm is a mathematical methodology used for detecting patterns in a training dataset. Some common algorithms are Linear regression, logistic regression, random forest, decision tree and XGBoost (Rajamani & Iyer, 2022).

Models are the mathematical objects that are built after learning from datasets, using statistical and probabilistic methods. Models are used for prediction and are the workhorse of ML. Artificial Intelligence AI is intelligent behaviour of machines, which mimic the human actions and interactions. Machine Learning is one of the paradigms of Artificial Intelligence. Natural language processing, Deep Learning, Computer vision are other paradigms of artificial intelligence (Elomaa et al., 2002).

TYPES OF MACHINE LEARNING MODELS

There are 2 types of models in ML Ecosystem namely: pre-trained models and self or custom-trained models. Pre-trained model files are ready made models which can be downloaded from sites like Kaggle.com and can immediately classify or predict using test or unseen data (Rajamani & Iyer, 2022). Self-trained model requires us to train the model using dataset which we generate ourselves or acquire from the internet. These models must be fine-tuned using various algorithms until they achieve a desired level of accuracy (Pazzani et al., 1991).Machine learning ML algorithm is a mathematical methodology used for detecting patterns in a training dataset. Some common algorithms are Linear regression, logistic regression, random forest, decision tree and XGBoost (Jobin et al., 2019).

DECISION TREES (DT) ALGORITHMS

Decision trees (DT) algorithms are a sequence of binary trees which branch into two branches or edges, based on some rule. The branch is called a leaf node. Functions are used to minimize node purity. Gini index is a function used on leaf node to determine the accuracy of the split. This index ranges from 0 to 1, zero where all observations belong to a class and 1 where every observation is random noise. For optimization or best decision of a leaf node we need limit of Gini as close to zero as possible(Rokach & Maimon, 2015).

Step by step process of categorizing an object by going through the process of Splitting the decision-making process into 2 pathways which are the 2 branches of the Decision node. The terminal outcomes are called Leaf nodes. This is one of the most common algorithms of ML.

The first decision node of the entire network is called the Root node. Pruning is the process akin to Pruning of the branches, where some of the redundant branches of a Decision node are removed. There are 2 types of DT, namely: 1. categorical variable decision tree -used to classify categorical variables 2. continuous variable decision tree- decision for continuous variables (Sullivan, 2017).

CROSS-VALIDATION PROCESS OF THE MODELS

Cross-validation is process of testing the model's performance on a test set after training on the training dataset. Problem of "overfitting" refers to the process by which the model becomes very fine tuned for the training data but performs poorly on test data set. This is a case where model fails to generalize based on training dataset. "Underfitting" is where model does poorly even on training dataset(Dargan et al., 2019).

Bagging/ Bootstrapping technique

Bagging is a technique that is used in machine learning to combine the predictions of multiple models. Bagging or Bootstrap aggregation is a machine learning algorithm where a subset of data is generated using Bootstrapping procedure to improve the performance and accuracy of ML model. The idea is to take the predictions of all the models and then use some voting algorithm to come up with a final prediction. There is a paradigm called "*Out-of-Bag error*" (OOBE) feature. This algorithm is only available in the R language, but not currently available in Python (Lior Rokach & Maimon, 2015).

Bootstrapping is a resampling technique where we take samples from our original dataset and then create new samples by sampling with replacement from those samples.

In other words, bootstrapping helps us to make inferences about our data by using the same data repeatedly which makes it an excellent tool for estimating confidence intervals.

There are many ways in which bootstrapping can be done, but one of them is called "bagging." This technique works by taking random subsets of your original dataset and training on those subsets. These subsets are called "bootstrap samples" or "bagging samples" or "training sets" (Shrestha & Mahmood, 2019).

VALIDATING A LINEAR REGRESSION MODEL

In Linear regression problems mean squared error (MSE), the mean absolute error (MAE), and the R2 are used in model validation. In regression classification problems, true positive rate (TPR), true negative rate (TNR), and accuracy (ACC) are used in validation. Tabulation of TPR, TNR, positive predictive value PPV, negative predictive value NPV and accuracy is called Confusion matrix. Area Under the receiver operating Curve (AUC) is trade-off between TPR and TNR, is another common parameter used in model validation. Error Function thus effectively predicts the errors in our model's predictions or classifications. This is the accuracy of the ML model. There are many general ML frameworks like Scikit-learn and NLTK natural language processing tool kit which are used for general purpose ML. Examples of machine learning (M.L.) frameworks (Shrestha & Mahmood, 2019).

COMPUTER VISION (C.V)

Computer vision (C.V) is a subfield of artificial intelligence focused on enabling computers to interpret and process visual data to understand the environment and various objects present. Using algorithms, computer vision seeks to automate tasks that require complex image analysis and would be too tedious or difficult for humans. It has become increasingly important with the emergence of digital technologies, as it can be applied virtually anywhere from medical diagnosis to self-driving cars (Liu, 2020). The development of computer vision has significantly impacted many areas such as robotics, facial recognition, autonomous vehicles, and machinery automation. Its potential for automating processes, completing sophisticated tasks quickly, and providing valuable insights continues to attract interest from researchers and businesses alike (Keller et al., 2016).

SWARM ALGORITHM

A swarm algorithm is a system of many agents that work together to solve a problem. The agents can be both artificial and organic. They can be used in many different fields such as data mining, robotics, and optimization. The idea behind the swarm algorithm is to find the best solution from many different solutions by having each agent specialize in one area and then combine their results to create a more accurate and complete solution (Pearce, 2011).

Network science/ Graph theory and applications in Machine Learning

Graph theory is a branch of mathematics that studies the properties of graphs and networks. Graph theory is a branch of mathematics that studies the properties of graphs and networks. It has many applications in computer science, chemistry, physics, biology, engineering, and other sciences (Merris, 2001).Graph theory can be used to find the shortest path between two nodes in a network or to study how information spreads through a social network. Graphs can also be used to represent physical systems such as electrical circuits or mechanical devices such as levers. Machine Learning Graph theory is a branch of machine learning. It consists of algorithms that are used to create graphs from data. Graphs are visual representations of the data, which can be used for various purposes. Graphs can be used for clustering, finding patterns in data, and predicting future events. They can also be used for classification and regression problems. Some examples of these problems include predicting the next word in a sentence or determining if two words share the same meaning (Bornholdt & Heinz Georg Schuster, 2006).

BIOINFORMATICS USING MACHINE LEARNING

Machine learning techniques have become increasingly important in bioinformatics, as they present a powerful tool to analyze and interpret the huge amount of data generated from genomic analysis. These approaches can be used to recognize and evaluate patterns that are difficult to detect manually, regardless of the size or complexity of the data sets. Machine learning methods can also reduce the time for decision making by automating processes in relation to gene expression and protein databases. The models developed based on this technology provide robust analyses with high specificity in areas such as sequence alignment, functional annotation, and disease classification. Furthermore, it has become practical to employ machine learning algorithms when refining existing techniques and computational workflows, thus allowing new insights into computationally intensive problems in biology. Ultimately, leveraging machine learning studies explores opportunities across different domains of bioinformatics research such as drug discovery, population genetics, protein structure prediction, phylogenetics inference and genome assembly refinement (Zhang & Rajapakse, 2009).

INTERNET OF THINGS (IOT)

Internet of Things (IoT) are common devices that are connected to the internet and gather data on customer usage patterns and product performance. The internet of things (IoT) is a network of physical objects — including devices, vehicles, buildings, and other items embedded with electronics, software, sensors, and connectivity that enable these objects to collect and exchange data. This creates an environment where objects can be sensed and controlled remotely across existing networks — resulting in improved efficiency, accuracy, and economic benefit (Schwartz, 2016).

IoT has unlocked new opportunities for businesses as well as individuals to capitalize on the increased access to data across various industries. It brings with it the potential to transform entire business models by providing predictive analytics, preventive maintenance alerts and automated operations that can result in a superior customer experience. Additionally, IoT provides the opportunity for people to stay connected with their surroundings through real-time notifications about their community or environment. Examples of this technology include connected appliances like refrigerators which not only help keep food fresh better but also can order groceries when necessary; smart homes equipped with security systems that automate tasks such as locking doors at night; and connected factories that monitor performance levels for rapid intervention if something goes wrong (Clickard, 2019).

R LANGUAGE FOR MACHINE LEARNING

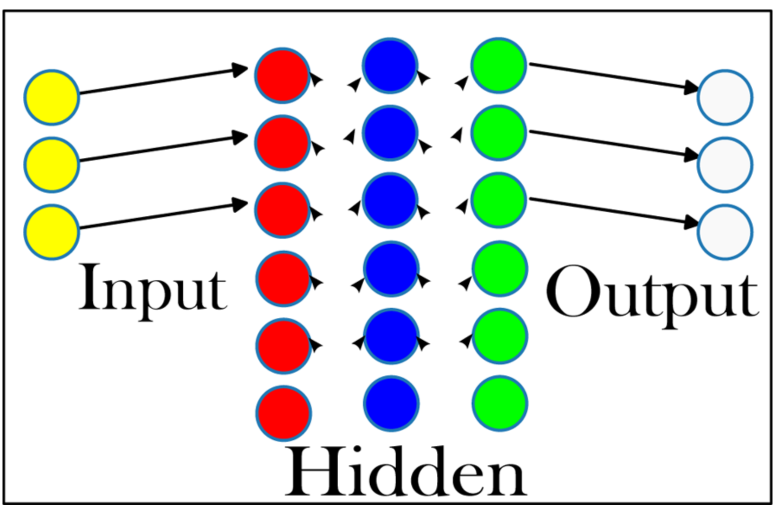
R is a programming language, is the second popular choice for Machine learning. R language (R Studio/Posit) is software environment for statistical computing and graphics. It is widely used among statisticians and data miners for developing statistical software and data analysis. R is also a popular choice for implementing machine learning algorithms and models, due to its rich ecosystem of libraries and frameworks for working with data like: forcats, tidyverse, tinyR. Some of the most used machine learning libraries in R include mlr3, xgboost, caret, randomForest, and gbm. These libraries provide efficient implementations of a wide range of machine learning algorithms, making it easy for R users to build and evaluate models. In addition, R's strong support for visualization and data exploration makes it a useful tool like ggplot2 and plotly, for understanding and interpreting the results of machine learning models. Despite availability of many tools (many more than Python as R has a longer history), free of cost, the language has considerable complex syntax, lack of compact installation and dependency on numerous distributed packages even for accomplishing a minor task, poses a practical hurdle in the actual usefulness of R language (Grolemund, 2015).

INTRODUCTION TO NEURAL NETWORKS

A Neural network is an artificial network of stimulated artificial neuron called Perceptron; these nodes are arranged in layers. This schematic is inspired by real life neurons of animal brains. Neural networks are basis of Natural Neural Network modelling ML framework like Keras, TensorFlow, Tensor board, Pytorch and Caffe2.

Weight of connection or link refers to the strength or weakness of link or influence between the individual neurons. These weights are adjustable and change in the process of learning. A burst of signal in the network is called Propagation.Data via input nodes produces a burst of activity in the network called Forward propagation. The adjustment involves both forward propagation of signal inputs through the network, as well as backward propagation of error terms generated by comparing actual output with expected output. In this way, the algorithm fine-tunes the weights and biases so that outputs more closely match desired results(Gurney, 2018).

Figure 1. Input nodes (yellow) feed data into the Neural network and Output nodes (white) harvest information from the network. There are few layers of processing nodes (red, blue, and green) which process the data based on predetermined algorithms. These nodes that are coloured red, blue, and green, are processing layers of nodes are called Hidden layers. The arrow represents the flow of information much like the synaptic connection of a real neuron.
Source: Gurney (2018)



FORWARD PROPAGATION

Forward Propagation is an algorithm that involves taking the data forward through a network of nodes. In this process, each node multiplies the input with a weight and adds bias to generate a single output value. This value is then passed on to the next layer and the process is repeated until an output layer value is calculated which can be used for prediction or classification. Forward Propagation is one of the key components in training neural networks as it eliminates the need for manual adjustments of weights and bias for every node-link combination. It also provides insights about how changes in parameters can affect overall performance (Yang & Shami, 2020).

ACTIVATION FUNCTIONS IN NEURAL NETWORKS

Activation functions are an important component in artificial neural network architecture. To determine the output of a layer we take the weighted sum of all the weight of the links and add a value called the Bias. This weighted sum is referred to as Activation. This Activation plus Bias is fed into a function called Activation function. This function acts like a gate and determines whether the signal will propagate to next layer or get discarded. Back propagation is the adjustment of weights of the links, to minimize the error in learning. Here the signal propagates in reverse direction.

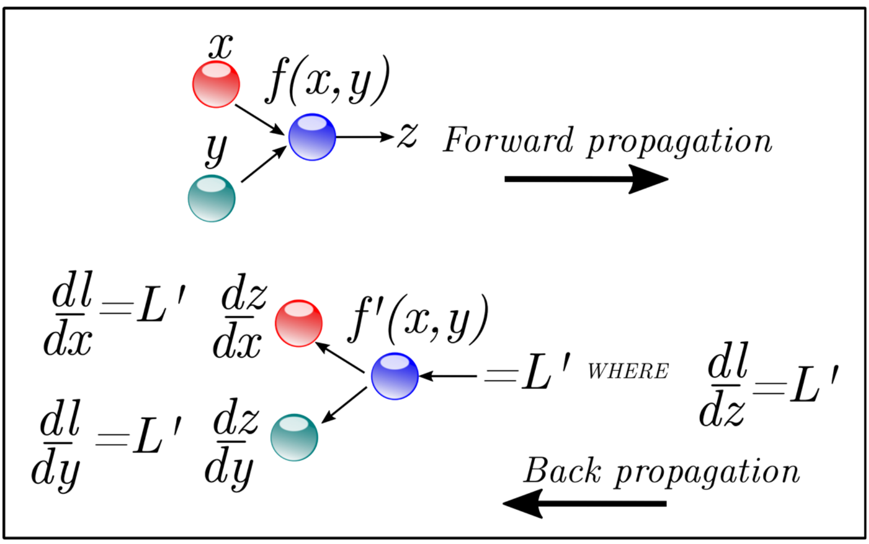
They are responsible for mapping a given input by a neuron to output within a specific range of values or classes, which enables neurons to compute non-linear boundaries between class labels and decrease variance in outputs. The role of activation functions is to calculate the weighted sum of inputs and pass those values as an input to the next layer. Activation functions also introduce non-linearity into the network, providing freedom from linear dependence on the inputs. There are several different types of activation functions such as sigmoid, hyperbolic tangent, ReLU and softmax among many others; each having its own unique purpose in developing an ANN model for various purposes(Dargan et al., 2019).

BACK PROPAGATION AND VANISHING GRADIENT PROBLEM

Back propagation is a popular supervised learning algorithm used in artificial neural networks. It is based on a cyclic process of optimization that adjusts the weights and biases to minimize a given cost function, thereby making the network better able to accurately respond to input signals. Back propagation has been widely used in various supervised applications such as image recognition, speech translation, and medical diagnosis(Sims, 2006).

During the process of Back propagation, the weights are updated in proportion to a partial derivative of the error function. Partial differentiation is done with respect to the current weight. An issue encountered in early stages of development of ML was that this derivative may become smaller and smaller tending to zero, effectively preventing any modification of weight, a classic ML problem known as 'vanishing gradient problem'. The exact opposite of this problem is 'exploding gradient problem', where derivative becomes so large that it starts tending to infinity (Stamile et al., 2021).

Figure 2. Scheme of forward and backward Propagation of signal in a neural network. Process of Back propagation, the weights are updated in proportion to a partial derivative of the error function which is L and derivative of L is L'.



Since, there is an exponential growth computational power of CPUs, GPUs and Cloud computing, the processor can compute smaller and smaller gradients to effectively jumping over the small gradient limitation and continue learning despite the Vanishing gradient, making Back propagation feasible (Xiaojin Xhu & Godberg, 2009).

Currently Back propagation is being investigated for efficiency, in correlation with biological system like our memories, which are Neural network can learn continuously without a pause, to update weights by Back propagation. Geoffrey Hinton in his preprint paper released in Dec 2022 has proposed that twice - Forward-Forward Algorithm maybe be more efficient and much simpler for learning. This comprises of one forward pass with positivedata and another forward pass the other with the negative data (Geoffrey Hinton in preprint paper "Forward-Forward Algorithm," under review, Dec 2022).

GPUs *Graphical Processing Units* comprise of multiple cores that can process large amounts of image data in parallel, parallel execution in form of threads, typically in computer games and video editing. GPU are programmed using frameworks such as NIVIDIA CUDA (https://developer.nvidia.com/cuda-zone) and OpenCL. Many ML applications like TensorFlow can utilize GPUs for enhanced performance.

Cloud computing refers to online storage, transmissions, and processing of data over fast and large bandwidth internet connection without storing information on the local computer. A cloud storage provider like the Amazon web services (AWS) supplies the users with required space and processing on-demand.

WEIGHT INITIALIZATION

Assignments of initial weights to various links or edges of a neural network is called "weight initialization". This must be a smaller value so that network can adjust the weights as it learns. Erroneous weight initialization can stop the network from learning. Optimization process is the adjustment of weights of a neural network by forward and Back propagation till the error function is minimized and a threshold of accuracy reached. Reinforcement is links or edges that are more important are given higher weight during learning process.

Weights initialization is a critical step in the optimization of machine learning models, particularly in deep learning. By initializing weights appropriately, it is possible to greatly improve the speed and accuracy of model convergence. Different approaches of weight initialization can also deal with vanishing or exploding gradients and reduce the risk of certain types of errors. As such, weights initialization plays a pivotal role in providing stability that enable training neural networks with greater accuracy and efficiency. Careful consideration must be taken when selecting an appropriate weight initialization strategy for a given problem as the choice can drastically alter optimization performance (Xiaojin Xhu & Godberg, 2009).

LATEST CUTTING-EDGE EXTENSIONS OF NEURAL NETWORKS

The most sophisticated and cutting-edge methods and tools in the area are referred to as the state of the art in machine learning. These strategies can be quite successful at resolving complicated issues since they frequently draw on the most recent research and innovations. Deep learning, which includes training enormous neural networks on data, is one of the state-of-the-art methods used in machine learning, as is reinforcement learning, which involves teaching agents to act in a way that maximizes rewards. In several fields, including image and audio recognition, natural language processing, and gaming, these techniques have produced outstanding results.

The subsequent section elucidates the bleeding-edge, latest extensions of neural networks as of December 2022.

CONVOLUTIONAL NEURAL NETWORKS (CNNS)

Convolutional neural networks (CNNs) are a powerful type of neural network that has become the go-to for many computers vision projects. The key differentiator is their use of convolutional layers, which allow them to work with multi-dimensional data. By converting inputted visual information into numerical representations that can be processed mathematically, CNNs can recognize patterns and making predictions in complex data sets. Beyond image processing, these networks can also be used for natural language processing and self-driven cars due to their ability to quickly identify features. They are uniquely adept at working with unstructured datasets and have found success in areas such as facial recognition and detections of objects in images (Yang & Shami, 2020).

BIDIRECTIONAL LONG SHORT-TERM MEMORY (BLSTM)

Bidirectional Long Short-Term Memory (BLSTM) is a recurrent neural network architecture that can effectively remember patterns in data over long periods of time. Unlike regular LSTMs, the BLSTM model can analyse both past and future information simultaneously. This makes it especially powerful for recognizing complex relationships between objects and events in time series data, such as sentiment analysis tasks or speech recognition applications. By incorporating this form of deep learning into artificial intelligence applications, machine learning models can better generalize long-term patterns and make more accurate predictions. Furthermore, rigorous testing has been conducted to demonstrate its excellent performance on a variety of natural language processing tasks including document classification and text generation. Ultimately, BLSTM proves to be an exemplary technique for amplifying the accuracy of advanced deep learning applications.

AI STARTS TALKING DRAWING PICTURES - STABLE DIFFUSION

A deep learning text-to-image model called Stable Diffusion was released in 2022. Stable Diffusion is a type of deep generative neural network, conceptualized by the LMU Munich-based CompVis research team. The Stable Diffusion model allows you to create new images from scratch by using a text prompt that describes which elements should be included or excluded from the output. Through its diffusion-denoising mechanism, the model can redraw existing images to incorporate new elements described by a text prompt (e.g., guided image synthesis)(Charlton, 2022).

Figure 3. Hyper-realistic outputs of Stable Diffusion, produced by prompting the AI engine using simple text prompts. Incredible that these 2 images were drawn by AI without any human intervention using Machine learning. These are public domain CC0 images according to the programmers of Stable diffusion engine.

DALL-E IMAGE SYNTHESIS PROGRAM

Dall-e, developed by OpenAI is an artificial intelligence system that uses natural language processing and computer vision to generate images based on text descriptions. It can draw complex scenes with a wide variety of objects and colours, such as rooms filled with furniture or modern cityscapes. It also works well in combination with other models, such as GPT-3; when these two models are combined, they can be used to generate realistic 3-dimensional images. Dall-e's impressive capabilities make it possible for us to create extremely detailed artworks that would otherwise take much more time and effort to draw manually. It also has potential practical applications, such as in the areas of visualization and augmented reality.

The Dall-e image synthesis program is a cutting-edge technology based on deep learning and natural language processing. Developed by OpenAI, the program can generate incredibly life-like visuals from simple text descriptions. For example, it can render 3D images of buildings when provided with detailed written directions, or accurately depict animals when given their species name. This impressive system is powered by a 12-billion parameter model called GPT-3 and an AI algorithm that recognizes patterns in text input. Perhaps most importantly, Dall-e creates objects that look real - unlike traditional computer-generated images which often do not match up to reality's complexity. Thus, this tool could revolutionize image creation in various industries like architecture and entertainment media (Bok & Langr, 2019).

Figure 4. Sample, output Dall-e image synthesis program which draws images using Artificial intelligence, Dall-e engine takes much longer time than Stable diffusion to render art, but quality of images is very good and realistic than Stable diffusion.

MIDJOURNEY'S ARTISTIC ENGINE VIA DISCORD BOT

Midjourney is Artificial Intelligence Discord bot that aims to provide users with an engaging and interactive communication interface. Like Open Ai's DALL-E and the open-source Stable Diffusion, Midjourney is an independent research lab that develops a private artificial intelligence application that generates visuals from textual descriptions. On July 12, 2022, the tool entered open beta, which it is presently in. David Holz, a founding member of Leap Motion, oversees the Midjourney team. Holz stated that the business was already profitable to The Register in August 2022. Using Midjourney's Discord bot commands, users produce art.

Currently, the only ways to access Midjourney are through a Discord bot on their main Discord, via direct messages, or by inviting the bot to a different server. Users use the /imagine command, like other AI art generator applications, and enter a prompt to produce images. Next, the bot produce art based on user prompt(Solanki et al., 2021).

AI STARTS TALKING – OPENAI'S CHATGPT

ChatGPT (GPT stands for Generative Pretrained Transformer) is an innovative chatbot technology based on the open source GPT-3 language model developed by OpenAI. By utilizing this natural language processing capabilities, ChatGPT can generate responses to customer inquiries that are highly accurate and personalized to the individual's specific context. ChatGPT can also be used in moderation scenarios to detect inappropriate messages and automatically respond with corrective actions. Additionally, it uses sentiment analysis of customers' messages and reacts accordingly making conversational experiences more natural and humane. Finally, its integration into existing CRM systems allows unified management of customer queries while scaling across multiple devices with ease(Pearce, 2011).

AI starts writing dramas- Deep Brain's Dramatron

Dramatron is a tool that may be used by authors to collaborate on screenplays and theatre scripts since it generates long, coherent texts using pre-trained, existing massive language models. For uniformity across the created text, Dramatron employs hierarchical tale generation. Dramatron dynamically creates character descriptions, story points, location descriptions, and dialogue starting from a log line. These generations offer material for compilation, editing, and rewriting by human authors.

Dramatron is intended to be used by writers as a writing tool, as well as a source of creativity and exploration. We worked with 15 playwrights and screenwriters in two-hour user study sessions to co-write screenplays with Dramatron to assess its usability and capabilities.One playwright staged four scripts that were co-written with Dramatron and significantly edited and reworked using Dramatron.

AI STARTS COMPOSING MUSIC- SOUNDFUL

Ada Lovelace (N 1815 –M 1852) is frequently considered as the first computer programmer and known for her algorithm contributions to Charles Babbage's Analytical Engine, the first analogue computer. She believed that the computer could compose music, today indeed with Artificial Intelligence computers can compose music and her wishful thinking of past century has come true.

AI-powered sites like https://soundful.com, are the latest development in this field where the user can quickly and easily create context-specific audio assets to customize their own unique soundful music. Thanks to advancements in neural networks and machine learning algorithms, AI can make use of data sets to generate realistic sounds that mimic real-world instruments as well as newer unheard possibilities. Furthermore, AI has allowed for accurate music stylization and interaction with users leading to more diverse personalized music experiences that aim to replicate creativity offloading a human touch. As this technology continues to grow, it will become easier for companies and individuals alike to access sophisticated musical tools that would be otherwise unattainable or too costly.

REGENERATIVE NEURAL NETWORK

An artificial neural network that can regenerate or heal itself when some parts break down or stop working is known as a regenerative neural network. A combination of hardware and software is utilized to create this kind of network, which is frequently employed in fields like medical technology, transportation systems, and military applications where a high level of availability and reliability is necessary.

The fundamental idea behind a regenerative neural network is that it can automatically identify and isolate any defective components before using a combination of backup mechanisms and self-healing algorithms to repair or replace the defective components without impairing the network's overall performance. This permits the network to continue working at full capacity, even in the state of partial failures or faults, RNN can keep running (Razavi, 2020).

One of the key benefits of employing a regenerative neural network is that, because the network can self-repair and continue operating without human involvement, it can help to eliminate the need for expensive and time-consuming maintenance.

Because there will be fewer downtime and other disturbances, this can also help the network be more dependable and available. Regenerative neural networks can also frequently adjust and learn from their experiences, which can help them develop over time and enhance their performance (Razavi, 2020).

Regenerative neural networks are frequently employed in systems that must have a high level of dependability and availability, such as in military, medical, and transportation applications. Here are some examples of use cases for regenerative neural networks:

Medical devices -To enable the continued operation of a medical device even if some of its components malfunction or fail, such as in implanted devices or monitoring systems.

Autonomous vehicles or drones - To allow the system to function even if some sensors or other components fail in transportation systems like Tesla, such as self-driving vehicles or drones.

Military applications- To allow the system to continue operating even in the event of damage or other disruptions in military applications, such as surveillance systems or unmanned vehicles.

Industrial Control systems -To allow the system to keep running even if some sensors or other components fail in industrial control systems, such as those used in manufacturing or power generation (Razavi, 2020).

To make it possible for financial systems, such as trading algorithms or fraud detection systems, to keep working even when some of its components break down or stop working properly (Razavi, 2020).

GENERATIVE NEURAL NETWORK

An artificial neural network called a generative neural network is made to produce fresh data that is comparable to training data. In applications like picture production, audio synthesis, or natural language processing, where it is intended to produce new data with the same properties as a given dataset, this sort of network is often utilized.

A generative neural network's main principle is that after being trained on a dataset of examples, it leverages that training to produce new data that is like the dataset's examples. This is accomplished by combining neural network topologies and machine learning algorithms, such as generative adversarial networks (GANs) or variation auto encoders (VAEs).

Machine learning models known as "generative models" are used to create fresh data that is comparable to an input. They can be used to produce new data points with the same properties as the training data after being trained on a dataset. In addition to producing new images, texts, or music that are like an input, generative models can also produce new data points that can be added to existing datasets. Variational auto encoders and generative adversarial networks (GANs) are two of the most well-liked generative models (VAEs). Deep learning approaches, which entail training big neural networks on plenty of data, are frequently used to train these models.

GENERATIVE ADVERSARIAL NETWORKS (GANS)

Generative adversarial networks (GANs) models are used to create new data that is comparable to an input. A generator network generates new data, while a discriminator network assesses the generated data to try to detect whether it is true or fraudulent. Together, the generator and discriminator networks are trained, with the generator attempting to produce data that can deceive the discriminator and the discriminator attempting to reliably discern between actual and fake data. It has been demonstrated that GANs can generate a wide range of data, including images, text, and audio, and that the results they produce are quite realistic and resemble real life (Ahirwar, 2019).

VARIATIONAL AUTOENCODERS (VAES)

To produce fresh data that is like an input, generative models called variational autoencoders (VAEs) are used. They can be used to produce new data points with the same properties as the training data after being trained on a dataset. Latent space, which is a representation of the data in a lower-dimensional space, is the foundation of the generative model class known as VAEs. By sampling from the latent space and then translating the data back into the original data space, this enables VAEs to produce new data points. VAEs have been demonstrated to yield very accurate results when used to generate a range of data, including images, text, and audio. It has been demonstrated that VAEs yield highly realistic results when employed to generate a range of data, including images, text, and audio (Bok & Langr, 2019).

DEEP GENERATIVE NEURAL NETWORKS

Deep generative neural networks are a powerful type of artificial intelligence that is capable of learning and producing high-dimensional data. Deep generative neural networks are composed of multiple layers, each with its own set of weights and connections. This allows them to learn the underlying structure of datasets, by learning how to map inputs and outputs into rich dimensional probability distributions. These networks can be used for a variety of applications, such as image recognition, voice generation, natural language processing, and even drug design. As deeper levels of analysis become more commonplace in AI research, these neural network architectures continue to improve accuracy, precision, and speed while simultaneously lowering hardware costs.

Utilizing generative neural networks has several benefits, one of which is its ability to create new data that is like a given dataset. This new data can then be used in a variety of applications. A generative neural network could be used, for instance, to produce new images that are like a training dataset of images or new audio samples that are comparable to a training dataset of audio samples. Applications like those for creating art, music, or languages can benefit from this. Furthermore, generative neural networks frequently learn and adapt over time, which can enhance their functionality and performance. In applications where it is desirable to produce new data with the same properties as a given dataset, generative neural networks are frequently utilized. Examples of specialized applications for generative neural networks include:

Produce new images in image generation that are comparable to a training dataset of images The creation of new artistic images based on a dataset of existing artworks or the generation of photographs from written descriptions could both be uses for this. Produce new audio samples for audio generation that are comparable to a training dataset of audio samples. This might be applied to making music or new sounds for video games or movies, among other things. Produce fresh text in natural language processing that is like a training text set. This might be applied to creating chatbots or creating new text passages based on a specific subject. Create novel chemical compounds that are like existing medications throughout the drug development process. This could be used to find prospective new medications with the needed properties. Produce new stock market data in finance that is comparable to a training dataset of stock market data This might be employed to evaluate trading algorithms or create fresh investment plans(Shrestha & Mahmood, 2019).

NATURAL LANGUAGE PROCESSING (NLP)

The branch of artificial intelligence known as “Natural Language Processing” (NLP) focuses on teaching computers how to comprehend, analyse, and produce human language. It involves analysing, comprehending, and producing natural language text or voice using computer algorithms and software. Natural language processing (NLP) is a form of artificial intelligence that enables computers to interpret, understand and generate human language. NLP incorporates techniques such as machine learning, deep learning, natural language understanding and natural language generation to analyse unstructured data like text and speech to produce actionable output that can be used for automated decision-making. By employing linguistic analysis methods such as text classification, sentiment analysis or automatic summarization, NLP helps to streamline manual processes, unlock insights from large volumes of data and enable the development of more efficient and precise solutions for problems across industries. Although natural language processing (NLP) is a broad field with many distinct techniques and approaches, some typical jobs that are usually connected with NLP include:

Text classification is the process of automatically classifying text into predetermined groups or classes using algorithms. A text classifier could be used, for instance, to categorize email communications as spam or not. Sentiment analysis is the process of automatically identifying the emotional content of text using algorithms. For instance, a sentiment analysis algorithm could be used to assess the positivity or negativity of a movie review.

Part-of-speech tagging is the process of automatically identifying the components of speech (such as nouns, verbs, and adjectives) in a given sentence using algorithms. Part-of-speech tagging is the process of automatically identifying the components of speech (such as nouns, verbs, and adjectives) in a given sentence using algorithms. Named entity recognition is the process of employing algorithms to recognize and categorize named entities (such as individuals, groups, and locations) in text. Utilizing algorithms to automatically translate text from one language to another is known as machine translation. In general, natural language processing is utilized in a wide range of applications, from voice assistants and chatbots to machine translation and text analysis, and it is essential for enabling computers to comprehend and produce human language (Goldberg, 2017).

LARGE LANGUAGE MODEL (LLM)

An artificial intelligence system known as a LargeLanguage model has been trained using a sizable amount of text data, including books, articles, and other written materials. This enables the model to produce text that is human-like and understand the structures and patterns of natural language. For tasks like language translation, text summarization, and producing conversational responses, large language models are frequently used. Large language models such as GPT-3 (Generative Pertained Transformer 3) and BERT are two well-known examples (Bidirectional Encoder Representations from Transformers). These models, which are referred to as “big,” may generate extremely accurate and natural-sounding text since they have been trained on a vast amount of data (Goldberg, 2017).

CONCLUSION

This chapter serves as a primer to young student of data science or computer science, introduces the concept of machine learning, artificial intelligence, neural networks, and their functioning. The second half highlights the latest developments in the field of Machine learning, recent and interesting advances in the application of machine learning, like ChatGPT and Stable diffusion. The chapter focuses on simplicity, and lucid language which should be easy to grasp for anyone who is interested in data sciences.

Finally, machine learning is an effective technique for forecasting and spotting trends in data. It has been effectively used to solve a variety of issues, including natural language processing, recommendation systems, and picture and speech recognition. The future of machine learning appears bright and promising, even though there are still numerous obstacles to be solved, such as improving the interpretability of models and resolving ethical issues. It has the potential to revolutionise a variety of sectors and enhance our daily lives with further study and development.

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