CONTENTS

KCS-055 : MACHINE LEARNING TECHNIQUES

1 UNIT

Introduction

CONTENTS

PART-1

Learning, Types of Learning.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.1. Define the term learning. What are the components of a learning system ?

Answer

1. Learning refers to the change in a subject's behaviour to a given situation brought by repeated experiences in that situation, provided that the behaviour changes cannot be explained on the basis of native response tendencies, matriculation or temporary states of the subject.
2. Learning agent can be thought of as containing a performance element that decides what actions to take and a learning element that modifies the performance element so that it makes better decisions.
3. The design of a learning element is affected by three major issues :
   a. Components of the performance element.
   b. Feedback of components.
   c. Representation of the components.

The important components of learning are :

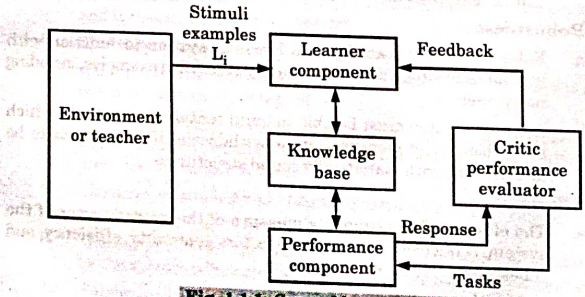


Fig. 1.1.1. General learning model.

1. **Acquisition of new knowledge :**
   a. One component of learning is the acquisition of new knowledge.

b. Simple data acquisition is easy for computers, even though it is difficult for people.

2. Problem solving :

The other component of learning is the problem solving that is required for both to integrate into the system, new knowledge that is presented to it and to deduce new information when required facts are not been presented.

Que 1.2. Write down the performance measures for learning.

Answer

Following are the performance measures for learning are :

1. Generality :

a. The most important performance measure for learning methods is the generality or scope of the method.

b. Generality is a measure of the case with which the method can be adapted to different domains of application.

c. A completely general algorithm is one which is a fixed or self adjusting configuration that can learn or adapt in any environment or application domain.

2. Efficiency :

a. The efficiency of a method is a measure of the average time required to construct the target knowledge structures from some specified initial structures.

b. Since this measure is often difficult to determine and is meaningless without some standard comparison time, a relative efficiency index can be used instead.

3. Robustness :

a. Robustness is the ability of a learning system to function with unreliable feedback and with a variety of training examples, including noisy ones.

b. A robust system must be able to build tentative structures which are subjected to modification or withdrawal if later found to be inconsistent with statistically sound structures.

4. Efficacy :

a. The efficacy of a system is a measure of the overall power of the system. It is a combination of the factors generality, efficiency, and robustness.

5. Ease of implementation :

a. Ease of implementation relates to the complexity of the programs and data structures, and the resources required to develop the given learning system.

b. Lacking good complexity metrics, this measure will often be somewhat subjective.

Que 1.3. Discuss supervised and unsupervised learning.

Answer

Supervised learning :

1. Supervised learning is also known as associative learning, in which the network is trained by providing it with input and matching output patterns.
2. Supervised training requires the pairing of each input vector with a target vector representing the desired output.
3. The input vector together with the corresponding target vector is called training pair.

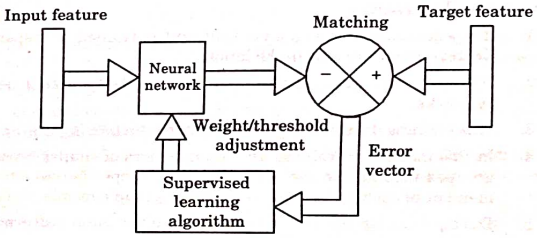


Fig. 1.3.1.

4. During the training session an input vector is applied to the network, and it results in an output vector.
5. This response is compared with the target response.
6. If the actual response differs from the target response, the network will generate an error signal.
7. This error signal is then used to calculate the adjustment that should be made in the synaptic weights so that the actual output matches the target output.
8. The error minimization in this kind of training requires a supervisor or teacher.
9. These input-output pairs can be provided by an external teacher, or by the system which contains the neural network (self-supervised).
10. Supervised training methods are used to perform non-linear mapping in pattern classification networks, pattern association networks and multilayer neural networks.

11. Supervised learning generates a global model that maps input objects to desired outputs.
12. In some cases, the map is implemented as a set of local models such as in case-based reasoning or the nearest neighbour algorithm.
13. In order to solve problem of supervised learning following steps are considered :
    i. Determine the type of training examples.
    ii. Gathering a training set.
    iii. Determine the input feature representation of the learned function.
    iv. Determine the structure of the learned function and corresponding learning algorithm.
    v. Complete the design.

Unsupervised learning :

1. It is a learning in which an output unit is trained to respond to clusters of pattern within the input.
2. Unsupervised training is employed in self-organizing neural networks.
3. This training does not require a teacher.
4. In this method of training, the input vectors of similar types are grouped without the use of training data to specify how a typical member of each group looks or to which group a member belongs.
5. During training the neural network receives input patterns and organizes these patterns into categories.
6. When new input pattern is applied, the neural network provides an output response indicating the class to which the input pattern belongs.
7. If a class cannot be found for the input pattern, a new class is generated.
8. Though unsupervised training does not require a teacher, it requires certain guidelines to form groups.
9. Grouping can be done based on color, shape and any other property of the object.
10. It is a method of machine learning where a model is fit to observations.
11. It is distinguished from supervised learning by the fact that there is no priori output.
12. In this, a data set of input objects is gathered.
13. It treats input objects as a set of random variables. It can be used in conjunction with Bayesian inference to produce conditional probabilities.

14. Unsupervised learning is useful for data compression and clustering.

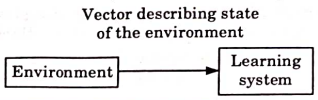


Fig. 1.3.2. Block diagram of unsupervised learning.

15. In unsupervised learning, system is supposed to discover statistically salient features of the input population.
16. Unlike the supervised learning paradigm, there is not a priori set of categories into which the patterns are to be classified; rather the system must develop its own representation of the input stimuli.

Que 1.4. **Describe briefly reinforcement learning ?**

Answer

1. Reinforcement learning is the study of how artificial system can learn to optimize their behaviour in the face of rewards and punishments.
2. Reinforcement learning algorithms have been developed that are closely related to methods of dynamic programming which is a general approach to optimal control.
3. Reinforcement learning phenomena have been observed in psychological studies of animal behaviour, and in neurobiological investigations of neuromodulation and addiction.

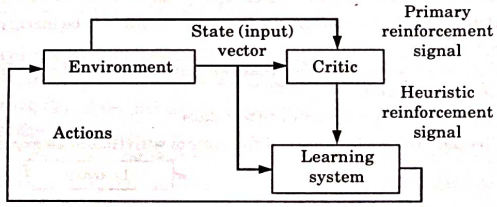


Fig. 1.4.1. Block diagram of reinforcement learning.

4. The task of reinforcement learning is to use observed rewards to learn an optimal policy for the environment.
5. An optimal policy is a policy that maximizes the expected total reward.
6. Without some feedback about what is good and what is bad, the agent will have no grounds for deciding which move to make.
7. The agents need to know that something good has happened when it wins and that something bad has happened when it loses.
8. This kind of feedback is called a reward or reinforcement.

9. Reinforcement learning is very valuable in the field of robotics, where the tasks to be performed are frequently complex enough to defy encoding as programs and no training data is available.
10. The robot's task consists of finding out, through trial and error (or success), which actions are good in a certain situation and which are not.
11. In many cases humans learn in a very similar way.
12. For example, when a child learns to walk, this usually happens without instruction, rather simply through reinforcement.
13. Successful attempts at working are rewarded by forward progress, and unsuccessful attempts are penalized by often painful falls.
14. Positive and negative reinforcement are also important factors in successful learning in school and in many sports.
15. In many complex domains, reinforcement learning is the only feasible way to train a program to perform at high levels.

Que 1.5. **What are the steps used to design a learning system ?**

Answer

Steps used to design a learning system are :

1. Specify the learning task.
2. Choose a suitable set of training data to serve as the training experience.
3. Divide the training data into groups or classes and label accordingly.
4. Determine the type of knowledge representation to be learned from the training experience.
5. Choose a learner classifier that can generate general hypotheses from the training data.
6. Apply the learner classifier to test data.
7. Compare the performance of the system with that of an expert human.

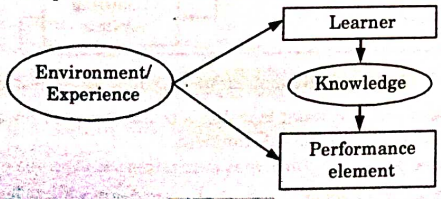


Fig. 1.5.1.

PART-2

Well Defined Learning Problems, Designing a Learning System.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.6. **Write short note on well defined learning problem with example.**

Answer

Well defined learning problem :

A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.

Three features in learning problems :

1. The class of tasks (T)
2. The measure of performance to be improved (P)
3. The source of experience (E)

For example :

1. **A checkers learning problem :**
   a. **Task (T) :** Playing checkers.
   b. **Performance measure (P) :** Percent of games won against opponents.
   c. **Training experience (E) :** Playing practice games against itself.
2. **A handwriting recognition learning problem :**
   a. **Task (T) :** Recognizing and classifying handwritten words within images.
   b. **Performance measure (P) :** Percent of words correctly classified.
   c. **Training experience (E) :** A database of handwritten words with given classifications.
3. **A robot driving learning problem :**
   a. **Task (T) :** Driving on public four-lane highways using vision sensors.
   b. **Performance measure (P) :** Average distance travelled before an error (as judged by human overseer).
   c. **Training experience (E) :** A sequence of images and steering commands recorded while observing a human driver.

Que 1.7. **Describe well defined learning problems role's in machine learning.**

Answer

Well defined learning problems role's in machine learning :

1. **Learning to recognize spoken words :**
   a. Successful speech recognition systems employ machine learning in some form.
   b. For example, the SPHINX system learns speaker-specific strategies for recognizing the primitive sounds (phonemes) and words from the observed speech signal.
   c. Neural network learning methods and methods for learning hidden Markov models are effective for automatically customizing to individual speakers, vocabularies, microphone characteristics, background noise, etc.
2. **Learning to drive an autonomous vehicle :**
   a. Machine learning methods have been used to train computer controlled vehicles to steer correctly when driving on a variety of road types.
   b. For example, the ALYINN system has used its learned strategies to drive unassisted at 70 miles per hour for 90 miles on public highways among other cars.
3. **Learning to classify new astronomical structures :**
   a. Machine learning methods have been applied to a variety of large databases to learn general regularities implicit in the data.
   b. For example, decision tree learning algorithms have been used by NASA to learn how to classify celestial objects from the second Palomar Observatory Sky Survey.
   c. This system is used to automatically classify all objects in the Sky Survey, which consists of three terabytes of image data.
4. **Learning to play world class backgammon :**
   a. The most successful computer programs for playing games such as backgammon are based on machine learning algorithms.
   b. For example, the world's top computer program for backgammon, TD-GAMMON learned its strategy by playing over one million practice games against itself.

PART-3

History of ML, Introduction of Machine Learning Approaches - (Artificial Neural Network, Clustering, Reinforcement Learning, Decision Tree Learning, Bayesian Network, Support Vector Machine, Genetic Algorithm).

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.8. **Describe briefly the history of machine learning.**

Answer

A. Early history of machine learning :

1. In 1943, neurophysiologist Warren McCulloch and mathematician Walter Pitts wrote a paper about neurons, and how they work. They created a model of neurons using an electrical circuit, and thus the neural network was created.
2. In 1952, Arthur Samuel created the first computer program which could learn as it ran.
3. Frank Rosenblatt designed the first artificial neural network in 1958, called Perceptron. The main goal of this was pattern and shape recognition.
4. In 1959, Bernard Widrow and Marcian Hoff created two models of neural network. The first was called ADELINE, and it could detect binary patterns. For example, in a stream of bits, it could predict what the next one would be. The second was called MADELINE, and it could eliminate echo on phone lines.

B. 1980s and 1990s :

1. In 1982, John Hopfield suggested creating a network which had bidirectional lines, similar to how neurons actually work.
2. Use of back propagation in neural networks came in 1986, when researchers from the Stanford psychology department decided to extend an algorithm created by Widrow and Hoff in 1962. This allowed multiple layers to be used in a neural network, creating what are known as 'slow learners', which will learn over a long period of time.
3. In 1997, the IBM computer Deep Blue, which was a chess-playing computer, beat the world chess champion.
4. In 1998, research at AT&T Bell Laboratories on digit recognition resulted in good accuracy in detecting handwritten postcodes from the US Postal Service.

C. 21st Century :

1. Since the start of the 21st century, many businesses have realised that machine learning will increase calculation potential. This is why they are researching more heavily in it, in order to stay ahead of the competition.

2. Some large projects include :
   i. GoogleBrain (2012)
   ii. AlexNet (2012)
   iii. DeepFace (2014)
   iv. DeepMind (2014)
   v. OpenAI (2015)
   vi. ResNet (2015)
   vii. U-net (2015)

Que 1.9. **Explain briefly the term machine learning.**

Answer

1. Machine learning is an application of Artificial Intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.
2. Machine learning focuses on the development of computer programs that can access data.
3. The primary aim is to allow the computers to learn automatically without human intervention or assistance and adjust actions accordingly.
4. Machine learning enables analysis of massive quantities of data.
5. It generally delivers faster and more accurate results in order to identify profitable opportunities or dangerous risks.
6. Combining machine learning with AI and cognitive technologies can make it even more effective in processing large volumes of information.

Que 1.10. **What are the applications of machine learning ?**

Answer

Following are the applications of machine learning :

1. **Image recognition :**
   a. Image recognition is the process of identifying and detecting an object or a feature in a digital image or video.
   b. This is used in many applications like systems for factory automation, toll booth monitoring, and security surveillance.
2. **Speech recognition :**
   a. Speech Recognition (SR) is the translation of spoken words into text.
   b. It is also known as Automatic Speech Recognition (ASR), computer speech recognition, or Speech To Text (STT).

   c. In speech recognition, a software application recognizes spoken words.
3. **Medical diagnosis :**
   a. ML provides methods, techniques, and tools that can help in solving diagnostic and prognostic problems in a variety of medical domains.
   b. It is being used for the analysis of the importance of clinical parameters and their combinations for prognosis.
4. **Statistical arbitrage :**
   a. In finance, statistical arbitrage refers to automated trading strategies that are typical of a short-term and involve a large number of securities.
   b. In such strategies, the user tries to implement a trading algorithm for a set of securities on the basis of quantities such as historical correlations and general economic variables.
5. **Learning associations :** Learning association is the process for discovering relations between variables in large data base.
6. **Extraction :**
   a. Information Extraction (IE) is another application of machine learning.
   b. It is the process of extracting structured information from unstructured data.

Que 1.11. **What are the advantages and disadvantages of machine learning ?**

Answer

Advantages of machine learning are :

1. **Easily identifies trends and patterns :**
   a. Machine learning can review large volumes of data and discover specific trends and patterns that would not be apparent to humans.
   b. For an e-commerce website like Flipkart, it serves to understand the browsing behaviours and purchase histories of its users to help cater to the right products, deals, and reminders relevant to them.
   c. It uses the results to reveal relevant advertisements to them.
2. **No human intervention needed (automation) :** Machine learning does not require physical force *i.e.*, no human intervention is needed.
3. **Continuous improvement :**
   a. ML algorithms gain experience, they keep improving in accuracy and efficiency.
   b. As the amount of data keeps growing, algorithms learn to make accurate predictions faster.

4. **Handling multi-dimensional and multi-variety data :**
   a. Machine learning algorithms are good at handling data that are multi-dimensional and multi-variety, and they can do this in dynamic or uncertain environments.

Disadvantages of machine learning are :

1. **Data acquisition :**
   a. Machine learning requires massive data sets to train on, and these should be inclusive/unbiased, and of good quality.
2. **Time and resources :**
   a. ML needs enough time to let the algorithms learn and develop enough to fulfill their purpose with a considerable amount of accuracy and relevancy.
   b. It also needs massive resources to function.
3. **Interpretation of results :**
   a. To accurately interpret results generated by the algorithms. We must carefully choose the algorithms for our purpose.
4. **High error-susceptibility :**
   a. Machine learning is autonomous but highly susceptible to errors.
   b. It takes time to recognize the source of the issue, and even longer to correct it.

Que 1.12. What are the advantages and disadvantages of different types of machine learning algorithm ?

Answer

Advantages of supervised machine learning algorithm :

1. Classes represent the features on the ground.
2. Training data is reusable unless features change.

Disadvantages of supervised machine learning algorithm :

1. Classes may not match spectral classes.
2. Varying consistency in classes.
3. Cost and time are involved in selecting training data.

Advantages of unsupervised machine learning algorithm :

1. No previous knowledge of the image area is required.
2. The opportunity for human error is minimised.
3. It produces unique spectral classes.
4. Relatively easy and fast to carry out.

Disadvantages of unsupervised machine learning algorithm :

1. The spectral classes do not necessarily represent the features on the ground.
2. It does not consider spatial relationships in the data.
3. It can take time to interpret the spectral classes.

Advantages of semi-supervised machine learning algorithm :

1. It is easy to understand.
2. It reduces the amount of annotated data used.
3. It is stable, fast convergent.
4. It is simple.
5. It has high efficiency.

Disadvantages of semi-supervised machine learning algorithm :

1. Iteration results are not stable.
2. It is not applicable to network level data.
3. It has low accuracy.

Advantages of reinforcement learning algorithm :

1. Reinforcement learning is used to solve complex problems that cannot be solved by conventional techniques.
2. This technique is preferred to achieve long-term results which are very difficult to achieve.
3. This learning model is very similar to the learning of human beings. Hence, it is close to achieving perfection.

Disadvantages of reinforcement learning algorithm :

1. Too much reinforcement learning can lead to an overload of states which can diminish the results.
2. Reinforcement learning is not preferable for solving simple problems.
3. Reinforcement learning needs a lot of data and a lot of computation.
4. The curse of dimensionality limits reinforcement learning for real physical systems.

Que 1.13. Write short note on Artificial Neural Network (ANN).

Answer

1. Artificial Neural Networks (ANN) or neural networks are computational algorithms that intended to simulate the behaviour of biological systems composed of neurons.

2. ANNs are computational models inspired by an animal's central nervous systems.
3. It is capable of machine learning as well as pattern recognition.
4. A neural network is an oriented graph. It consists of nodes which in the biological analogy represent neurons, connected by arcs.
5. It corresponds to dendrites and synapses. Each arc associated with a weight at each node.
6. A neural network is a machine learning algorithm based on the model of a human neuron. The human brain consists of millions of neurons.
7. It sends and process signals in the form of electrical and chemical signals.
8. These neurons are connected with a special structure known as synapses. Synapses allow neurons to pass signals.
9. An Artificial Neural Network is an information processing technique. It works like the way human brain processes information.
10. ANN includes a large number of connected processing units that work together to process information. They also generate meaningful results from it.

Que 1.14. Write short note on clustering.

Answer

1. Clustering is a division of data into groups of similar objects.
2. Each group or cluster consists of objects that are similar among themselves and dissimilar to objects of other groups as shown in Fig. 1.14.1.

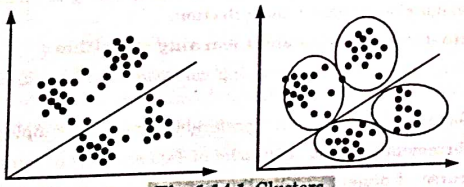


Fig. 1.14.1. Clusters.

3. A cluster is a collection of data objects that are similar to one another within the same cluster and are dissimilar to the object in the other cluster.
4. Clusters may be described as connected regions of a multidimensional space containing relatively high density points, separated from each other by a region containing a relatively low density points.
5. From the machine learning perspective, clustering can be viewed as unsupervised learning of concepts.
6. Clustering analyzes data objects without help of known class label.

7. In clustering, the class labels are not present in training data simply because they are not known to cluster the data objects.
8. Hence, it is the type of unsupervised learning.
9. For this reason, clustering is a form of learning by observation rather than learning by examples.
10. There are certain situations where clustering is useful. These include :
    a. The collection and classification of training data can be costly and time consuming. Therefore it is difficult to collect a training data set. A large number of training samples are not all labelled. Then it is useful to train a supervised classifier with a small portion of training data and then use clustering procedures to tune the classifier based on the large, unclassified dataset.
    b. For data mining, it can be useful to search for grouping among the data and then recognize the cluster.
    c. The properties of feature vectors can change over time. Then, supervised classification is not reasonable. Because the test feature vectors may have completely different properties.
    d. The clustering can be useful when it is required to search for good parametric families for the class conditional densities, in case of supervised classification.

Que 1.15. What are the applications of clustering ?

Answer

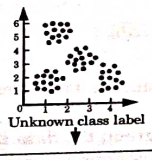
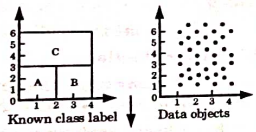
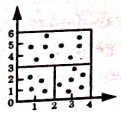
Following are the applications of clustering :

1. **Data reduction :**
    a. In many cases, the amount of available data is very large and its processing becomes complicated.
    b. Cluster analysis can be used to group the data into a number of clusters and then process each cluster as a single entity.
    c. In this way, data compression is achieved.
2. **Hypothesis generation :**
    a. In this case, cluster analysis is applied to a data set to infer hypothesis that concerns about the nature of the data.
    b. Clustering is used here to suggest hypothesis that must be verified using other data sets.
3. **Hypothesis testing :** In this context, cluster analysis is used for the verification of the validity of a specific hypothesis.
4. **Prediction based on groups :**
    a. In this case, cluster analysis is applied to the available data set and then the resulting clusters are characterized based on the characteristics of the patterns by which they are formed.

b. In this sequence, if an unknown pattern is given, we can determine the cluster to which it is more likely to belong and characterize it based on the characterization of the respective cluster.

Que 1.16. Differentiate between clustering and classification.

Answer

S.No.	Clustering	Classification
1.	Clustering analyzes data objects without known class label.	In classification, data are grouped by analyzing the data objects whose class label is known.
2.	There is no prior knowledge of the attributes of the data to form clusters.	There is some prior knowledge of the attributes of each classification.
3.	It is done by grouping only the input data because output is not predefined.	It is done by classifying output based on the values of the input data.
4.	The number of clusters is not known before clustering. These are identified after the completion of clustering. 	The number of classes is known before classification as there is predefined output based on input data. 
5.		
6.	It is considered as unsupervised learning because there is no prior knowledge of the class labels.	It is considered as the supervised learning because class labels are known before.

Que 1.17. What are the various clustering techniques ?

Answer

1. Clustering techniques are used for combining observed examples into clusters or groups which satisfy two following main criteria :
   a. Each group or cluster is homogeneous *i.e.*, examples belong to the same group are similar to each other.
   b. Each group or cluster should be different from other clusters *i.e.*, examples that belong to one cluster should be different from the examples of the other clusters.
2. Depending on the clustering techniques, clusters can be expressed in different ways :
   a. Identified clusters may be exclusive, so that any example belongs to only one cluster.
   b. They may be overlapping *i.e.*, an example may belong to several clusters.
   c. They may be probabilistic *i.e.*, an example belongs to each cluster with a certain probability.
   d. Clusters might have hierarchical structure.

Major classifications of clustering techniques are :

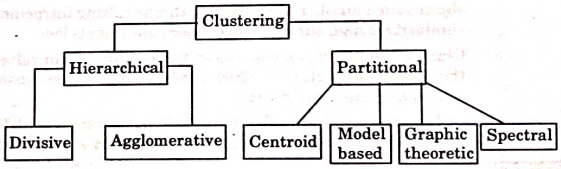


Fig. 1.17.1. Types of clustering.

   a. Once a criterion function has been selected, clustering becomes a well-defined problem in discrete optimization. We find those partitions of the set of samples that extremize the criterion function.
   c. The sample set is finite, there are only a finite number of possible partitions.
   d. The clustering problem can always be solved by exhaustive enumeration.

1. **Hierarchical clustering :**
   a. This method works by grouping data object into a tree of clusters.
   b. This method can be further classified depending on whether the hierarchical decomposition is formed in bottom up (merging) or top down (splitting) fashion.

Following are the two types of hierarchical clustering :

a. **Agglomerative hierarchical clustering :** This bottom up strategy starts by placing each object in its own cluster and then merges these atomic clusters into larger and larger clusters, until all of the objects are in a single cluster.

b. **Divisive hierarchical clustering :**

i. This top down strategy does the reverse of agglomerative strategy by starting with all objects in one cluster.

ii. It subdivides the cluster into smaller and smaller pieces until each object forms a cluster on its own.

2. **Partitional clustering :**

a. This method first creates an initial set of number of partitions where each partition represents a cluster.

b. The clusters are formed to optimize an objective partition criterion such as a dissimilarity function based on distance so that the objects within a cluster are similar whereas the objects of different clusters are dissimilar.

Following are the types of partitioning methods :

a. **Centroid based clustering :**

i. In this, it takes the input parameter and partitions a set of object into a number of clusters so that resulting intracluster similarity is high but the intercluster similarity is low.

ii. Cluster similarity is measured in terms of the mean value of the objects in the cluster, which can be viewed as the cluster's centroid or center of gravity.

b. **Model-based clustering :** This method hypothesizes a model for each of the cluster and finds the best fit of the data to that model.

Que 1.18. Describe reinforcement learning.

Answer

1. Reinforcement learning is the study of how animals and artificial systems can learn to optimize their behaviour in the face of rewards and punishments.
2. Reinforcement learning algorithms related to methods of dynamic programming which is a general approach to optimal control.
3. Reinforcement learning phenomena have been observed in psychological studies of animal behaviour, and in neurobiological investigations of neuromodulation and addiction.
4. The task of reinforcement learning is to use observed rewards to learn an optimal policy for the environment. An optimal policy is a policy that maximizes the expected total reward.

Que 1.19. Explain decision tree in detail.

Answer

1. A decision tree is a flowchart structure in which each internal node represents a test on a feature, each leaf node represents a class label and branches represent conjunctions of features that lead to those class labels.
2. The paths from root to leaf represent classification rules.
3. Fig 1.19.1, illustrate the basic flow of decision tree for decision making with labels (Rain(Yes), Rain(No)).

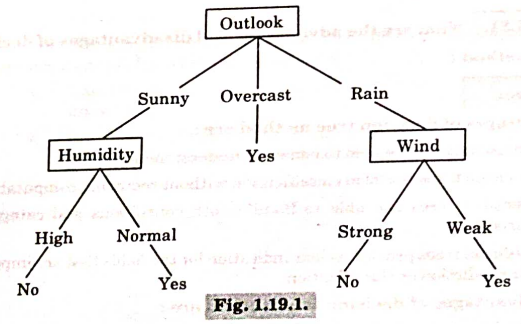


Fig. 1.19.1.

4. Decision tree is the predictive modelling approach used in statistics, data mining and machine learning.
5. Decision trees are constructed via an algorithmic approach that identifies the ways to split a data set based on different conditions.
6. Decision trees are a non-parametric supervised learning method used for both classification and regression tasks.
7. Classification trees are the tree models where the target variable can take a discrete set of values.
8. Regression trees are the decision trees where the target variable can take continuous set of values.

Que 1.20. What are the steps used for making decision tree ?

Answer

Steps used for making decision tree are :

1. Get list of rows (dataset) which are taken into consideration for making decision tree (recursively at each node).

2. Calculate uncertainty of our dataset or Gini impurity or how much our data is mixed up etc.
3. Generate list of all question which needs to be asked at that node.
4. Partition rows into True rows and False rows based on each question asked.
5. Calculate information gain based on Gini impurity and partition of data from previous step.
6. Update highest information gain based on each question asked.
7 Update question based on information gain (higher information gain).
8. Divide the node on question. Repeat again from step 1 until we get pure node (leaf nodes).

Que 1.21. What are the advantages and disadvantages of decision tree method ?

Answer

Advantages of decision tree method are :

1. Decision trees are able to generate understandable rules.
2. Decision trees perform classification without requiring computation.
3. Decision trees are able to handle both continuous and categorical variables.
4. Decision trees provide a clear indication for the fields that are important for prediction or classification.

Disadvantages of decision tree method are :

1. Decision trees are less appropriate for estimation tasks where the goal is to predict the value of a continuous attribute.
2. Decision trees are prone to errors in classification problems with many class and relatively small number of training examples.
3. Decision tree are computationally expensive to train. At each node, each candidate splitting field must be sorted before its best split can be found.
4. In decision tree algorithms, combinations of fields are used and a search must be made for optimal combining weights. Pruning algorithms can also be expensive since many candidate sub-trees must be formed and compared.

Que 1.22. Write short note on Bayesian belief networks.

Answer

1. Bayesian belief networks specify joint conditional probability distributions.
2. They are also known as belief networks, Bayesian networks, or probabilistic networks.

3. A Belief Network allows class conditional independencies to be defined between subsets of variables.
4. It provides a graphical model of causal relationship on which learning can be performed.
5. We can use a trained Bayesian network for classification.
6. There are two components that define a Bayesian belief network :

a. Directed acyclic graph :

i. Each node in a directed acyclic graph represents a random variable.

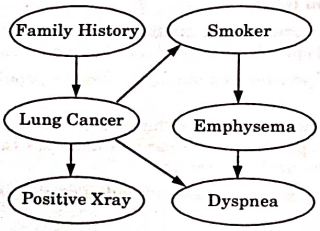
ii. These variable may be discrete or continuous valued.

iii. These variables may correspond to the actual attribute given in the data.

Directed acyclic graph representation : The following diagram shows a directed acyclic graph for six Boolean variables.

i. The arc in the diagram allows representation of causal knowledge.

ii. For example, lung cancer is influenced by a person's family history of lung cancer, as well as whether or not the person is a smoker.



iii. It is worth noting that the variable Positive X-ray is independent of whether the patient has a family history of lung cancer or that the patient is a smoker, given that we know the patient has lung cancer.

b. Conditional probability table :

The conditional probability table for the values of the variable LungCancer (LC) showing each possible combination of the values of its parent nodes, FamilyHistory (FH), and Smoker (S) is as follows :

	FH,S	FH,-S	-FH,S	-FH,S
LC	0.8	0.5	0.7	0.1
-LC	0.2	0.5	0.3	0.9

Que 1.23. **Write a short note on support vector machine.**

Answer

1. A Support Vector Machine (SVM) is machine learning algorithm that analyzes data for classification and regression analysis.
2. SVM is a supervised learning method that looks at data and sorts it into one of two categories.
3. An SVM outputs a map of the sorted data with the margins between the two as far apart as possible.
4. Applications of SVM :
   i. Text and hypertext classification
   ii. Image classification
   iii. Recognizing handwritten characters
   iv. Biological sciences, including protein classification

Que 1.24. **Explain genetic algorithm with flow chart.**

Answer

Genetic algorithm (GA) :

1. The genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection.
2. The genetic algorithm repeatedly modifies a population of individual solutions.
3. At each step, the genetic algorithm selects individuals at random from the current population to be parents and uses them to produce the children for the next generation.
4. Over successive generations, the population evolves toward an optimal solution.

Flow chart : The genetic algorithm uses three main types of rules at each step to create the next generation from the current population :

a. **Selection rule :** Selection rules select the individuals, called parents, that contribute to the population at the next generation.

b. **Crossover rule :** Crossover rules combine two parents to form children for the next generation.

c. **Mutation rule :** Mutation rules apply random changes to individual parents to form children.

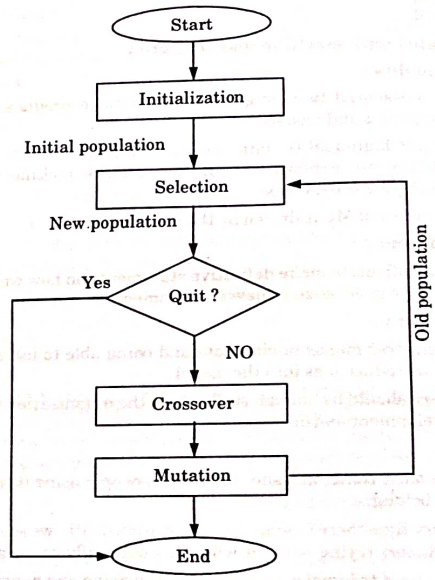


Fig. 1.24.1.

PART-4

Issues in Machine Learning and Data Science Vs. Machine Learning.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.25. **Briefly explain the issues related with machine learning.**

Answer

Issues related with machine learning are :

1. **Data quality :**
   a. It is essential to have good quality data to produce quality ML algorithms and models.
   b. To get high-quality data, we must implement data evaluation, integration, exploration, and governance techniques prior to developing ML models.
   c. Accuracy of ML is driven by the quality of the data.
2. **Transparency :**
   a. It is difficult to make definitive statements on how well a model is going to generalize in new environments.
3. **Manpower :**
   a. Manpower means having data and being able to use it. This does not introduce bias into the model.
   b. There should be enough skill sets in the organization for software development and data collection.
4. **Other :**
   a. The most common issue with ML is people using it where it does not belong.
   b. Every time there is some new innovation in ML, we see overzealous engineers trying to use it where it's not really necessary.
   c. This used to happen a lot with deep learning and neural networks.
   d. Traceability and reproduction of results are two main issues.

Que 1.26. What are the classes of problem in machine learning ?

Answer

Common classes of problem in machine learning :

1. **Classification :**
   a. In classification data is labelled *i.e.*, it is assigned a class, for example, spam/non-spam or fraud/non-fraud.
   b. The decision being modelled is to assign labels to new unlabelled pieces of data.
   c. This can be thought of as a discrimination problem, modelling the differences or similarities between groups.
2. **Regression :**
   a. Regression data is labelled with a real value rather than a label.
   b. The decision being modelled is what value to predict for new unpredicted data.

3. **Clustering :**
   a. In clustering data is not labelled, but can be divided into groups based on similarity and other measures of natural structure in the data.
   b. For example, organising pictures by faces without names, where the human user has to assign names to groups, like iPhoto on the Mac.
4. **Rule extraction :**
   a. In rule extraction, data is used as the basis for the extraction of propositional rules.
   b. These rules discover statistically supportable relationships between attributes in the data.

Que 1.27. Differentiate between data science and machine learning.

Answer

S. No.	Data science	Machine learning
1.	Data science is a concept used to tackle big data and includes data cleansing, preparation, and analysis.	Machine learning is defined as the practice of using algorithms to use data, learn from it and then forecast future trends for that topic.
2.	It includes various data operations.	It includes subset of Artificial Intelligence.
3.	Data science works by sourcing, cleaning, and processing data to extract meaning out of it for analytical purposes.	Machine learning uses efficient programs that can use data without being explicitly told to do so.
4.	SAS, Tableau, Apache, Spark, MATLAB are the tools used in data science.	Amazon Lex, IBM Watson Studio, Microsoft Azure ML Studio are the tools used in ML.
5.	Data science deals with structured and unstructured data.	Machine learning uses statistical models.
6.	Fraud detection and healthcare analysis are examples of data science.	Recommendation systems such as Spotify and Facial Recognition are examples of machine learning.

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2 UNIT

Regression and Bayesian Learning

CONTENTS

PART-1

Regression, Linear Regression and Logistic Regression.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.1. Define the term regression with its type.

Answer

1. Regression is a statistical method used in finance, investing, and other disciplines that attempts to determine the strength and character of the relationship between one dependent variable (usually denoted by Y) and a series of other variables (known as independent variables).
2. Regression helps investment and financial managers to value assets and understand the relationships between variables, such as commodity prices and the stocks of businesses dealing in those commodities.

There are two type of regression :

a. Simple linear regression : It uses one independent variable to explain or predict the outcome of dependent variable Y.

$$Y = a + bX + u$$

b. Multiple linear regression : It uses two or more independent variables to predict outcomes.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_tX_t + u$$

Where :

Y = The variable we you are trying to predict (dependent variable).

X = The variable that we are using to predict Y (independent variable).

a = The intercept.

b = The slope.

u = The regression residual.

Que 2.2. Describe briefly linear regression.

Answer

1. Linear regression is a supervised machine learning algorithm where the predicted output is continuous and has a constant slope.
2. It is used to predict values within a continuous range, (for example : sales, price) rather than trying to classify them into categories (for example : cat, dog).

3. Following are the types of linear regression :

a. Simple regression :

i. Simple linear regression uses traditional slope-intercept form to produce accurate prediction, $y = mx + b$
where, m and b are the variables,
x represents our input data and y represents our prediction.

b. Multivariable regression :

i. A multi-variable linear equation is given below, where w represents the coefficients, or weights :
$$f(x, y, z) = w_1x + w_2y + w_3z$$

ii. The variables x, y, z represent the attributes, or distinct pieces of information that, we have about each observation.

iii. For sales predictions, these attributes might include a company's advertising spend on radio, TV, and newspapers.
$$\text{Sales} = w_1 \text{ Radio} + w_2 \text{TV} + w_3 \text{Newspapers}$$

Que 2.3. Explain logistics regression.

Answer

1. Logistic regression is a supervised learning classification algorithm used to predict the probability of a target variable.
2. The nature of target or dependent variable is dichotomous, which means there would be only two possible classes.
3. The dependent variable is binary in nature having data coded as either 1 (stands for success/yes) or 0 (stands for failure/no).
4. A logistic regression model predicts $P(Y = 1)$ as a function of X. It is one of the simplest *ML* algorithms that can be used for various classification problems such as spam detection, diabetes prediction, cancer detection etc.

Que 2.4. What are the types of logistics regression ?

Answer

Logistics regression can be divided into following types :

1. **Binary (Binomial) Regression :**
   a. In this classification, a dependent variable will have only two possible types either 1 and 0.
   b. For example, these variables may represent success or failure, yes or no, win or loss etc.
2. **Multinomial regression :**
   a. In this classification, dependent variable can have three or more possible unordered types or the types having no quantitative significance.
   b. For example, these variables may represent "Type *A*" or "Type *B*" or "Type *C*".

3. **Ordinal regression :**
   a. In this classification, dependent variable can have three or more possible ordered types or the types having a quantitative significance.
   b. For example, these variables may represent "poor" or "good", "very good", "Excellent" and each category can have the scores like 0, 1, 2, 3.

Que 2.5. Differentiate between linear regression and logistics regression.

Answer

S. No.	Linear regression	Logistics regression
1.	Linear regression is a supervised regression model.	Logistic regression is a supervised classification model.
2.	In Linear regression, we predict the value by an integer number.	In Logistic regression, we predict the value by 1 or 0.
3.	No activation function is used.	Activation function is used to convert a linear regression equation to the logistic regression equation.
4.	A threshold value is added.	No threshold value is needed.
5.	It is based on the least square estimation.	The dependent variable consists of only two categories.
6.	Linear regression is used to estimate the dependent variable in case of a change in independent variables.	Logistic regression is used to calculate the probability of an event.
7.	Linear regression assumes the normal or gaussian distribution of the dependent variable.	Logistic regression assumes the binomial distribution of the dependent variable.

PART-2

Bayesian Learning, Bayes Theorem, Concept Learning, Bayes Optimal Classifier, Naive Bayes Classifier, Bayesian Belief Networks, EM Algorithm.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.6. **Explain Bayesian learning. Explain two category classification.**

Answer

Bayesian learning :

1. Bayesian learning is a fundamental statistical approach to the problem of pattern classification.
2. This approach is based on quantifying the tradeoffs between various classification decisions using probability and costs that accompany such decisions.
3. Because the decision problem is solved on the basis of probabilistic terms, hence it is assumed that all the relevant probabilities are known.
4. For this we define the state of nature of the things present in the particular pattern. We denote the state of nature by ω.

Two category classification :

1. Let ω_1, ω_2 be the two classes of the patterns. It is assumed that the a priori probabilities $p(\omega_1)$ and $p(\omega_2)$ are known.
2. Even if they are not known, they can easily be estimated from the available training feature vectors.
3. If N is total number of available training patterns and N_1, N_2 of them belong to ω_1 and ω_2, respectively then $p(\omega_1) = N_1/N$ and $p(\omega_2) = N_2/N$.
4. The conditional probability density functions $p(x \mid \omega_i)$, $i = 1, 2$ is also assumed to be known which describes the distribution of the feature vectors in each of the classes.
5. The feature vectors can take any value in the l-dimensional feature space.
6. Density functions $p(x \mid \omega_i)$ become probability and will be denoted by $p(x \mid \omega_i)$ when the feature vectors can take only discrete values.
7. Consider the conditional probability,

$$p(\omega_i \mid x) = \frac{p(x \mid \omega_i) p(\omega_i)}{p(x)} \quad \ldots(2.6.1)$$

where $p(x)$ is the probability density function of x and for which we have

$$p(x) = \sum_{i=1}^{2} p(x \mid \omega_i) p(\omega_i) \quad \ldots(2.6.2)$$

8. Now, the Baye's classification rule can be defined as :
   a. If $p(\omega_1 \mid x) > p(\omega_2 \mid x)$ x is classified to ω_1
   b. If $p(\omega_1 \mid x) < p(\omega_2 \mid x)$ x is classified to ω_2 ...(2.6.3)
9. In the case of equality the pattern can be assigned to either of the two classes. Using equation (2.6.1), decision can equivalently be based on the inequalities :
   a. $p(x \mid \omega_1) p(\omega_1) > p(x \mid \omega_2) p(\omega_2)$
   b. $p(x \mid \omega_1) p(\omega_1) < p(x \mid \omega_2) p(\omega_2)$ ...(2.6.4)
10. Here $p(x)$ is not taken because it is same for all classes and it does not affect the decision.
11. Further, if the priori probabilities are equal, *i.e.*,
    a. $p(\omega_1) = p(\omega_2) = 1/2$ then Eq. (2.6.4) becomes,
    b. $p(x \mid \omega_1) > p(x \mid \omega_2)$
    c. $p(x \mid \omega_1) < p(x \mid \omega_2)$
12. For example, in Fig. 2.6.1, two equiprobable classes are presented which shows the variations of $p(x \mid \omega_i)$, $i = 1, 2$ as functions of x for the simple case of a single feature ($l = 1$).
13. The dotted line at x_0 is a threshold which partitions the space into two regions, R_1 and R_2. According to Baye's decisions rule, for all value of x in R_1 the classifier decides ω_1 and for all values in R_2 it decides ω_2.
14. From the Fig. 2.6.1, it is obvious that the errors are unavoidable. There is a finite probability for an x to lie in the R_2 region and at the same time to belong in class ω_1. Then there is error in the decision.

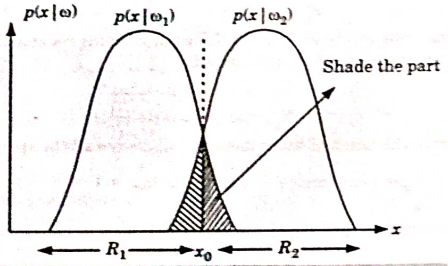


Fig. 2.6.1. Bayesian classifier for the case of two equiprobable classes.

15. The total probability, P of committing a decision error for two equiprobable classes is given by,

$$P_e = \frac{1}{2} \int_{-\infty}^{x_0} p(x \mid \omega_2) dx + \frac{1}{2} \int_{x_0}^{1-\infty} p(x \mid \omega_1) dx$$

which is equal to the total shaded area under the curves in Fig. 2.6.1.

Que 2.7. Explain how the decision error for Bayesian classification can be minimized.

Answer

1. Bayesian classifier can be made optimal by minimizing the classification error probability.
2. In Fig. 2.7.1, it is observed that when the threshold is moved away from x_0, the corresponding shaded area under the curves always increases.
3. Hence, we have to decrease this shaded area to minimize the error.
4. Let R_1 be the region of the feature space for ω_1 and R_2 be the corresponding region for ω_2.
5. Then an error will be occurred if, $x \in R_1$ although it belongs to ω_2 or if $x \in R_2$ although it belongs to ω_1 *i.e.*,

$$P_e = p(x \in R_2, \omega_1) + p(x \in R_1, \omega_2) \quad ...(2.7.1)$$

6. P_e can be written as,

$$P_e = p(x \in R_2 | \omega_1)\, p(\omega_1) + p(x \in R_1 | \omega_2)\, p(\omega_2)$$

$$= P(\omega_1) \int_{R_2} p(x | \omega_1)dx + p(\omega_2) \int_{R_1} p(x | \omega_2)dx \quad ...(2.7.2)$$

7. Using the Baye's rule,

$$= P \int_{R_2} p(\omega_1 | x)p(x)dx + \int_{R_1} p(\omega_2 | x)p(x)dx \quad ...(2.7.3)$$

8. The error will be minimized if the partitioning regions R_1 and R_2 of the feature space are chosen so that

$$R_1 : p(\omega_1 | x) > p(\omega_2 | x)$$
$$R_2 : p(\omega_2 | x) > p(\omega_1 | x) \quad ...(2.7.4)$$

9. Since the union of the regions R_1, R_2 covers all the space, we have

$$\int_{R_1} p(\omega_1 | x)p(x)dx + \int_{R_2} p(\omega_1 | x)p(x)dx = 1 \quad ...(2.7.5)$$

10. Combining equation (2.7.3) and (2.7.5), we get,

$$P_e = p(w_1) \int_{R_1} (p(\omega_1 | x) - p(\omega_2 | x))\, p(x)dx \quad ...(2.7.6)$$

11. Thus, the probability of error is minimized if R_1 is the region of space in which $p(\omega_1 | x) > p(\omega_2 | x)$. Then R_2 becomes region where the reverse is true.

12. In a classification task with M classes, $\omega_1, \omega_2, ..., \omega_M$ an unknown pattern, represented by the feature vector x, is assigned to class ω_i if $p(\omega_i | x) > p(\omega_j | x)\ \forall\ j \neq i$.

Que 2.8. Consider the Bayesian classifier for the uniformly distributed classes, where :

$$P(x/w_1) = \begin{cases} \dfrac{1}{a_2 - a_1}, & x \in [a_1, a_2] \\ 0, & \text{muullion} \end{cases}$$

$$P(x/w_2) = \begin{cases} \dfrac{1}{b_2 - b_1}, & x \in [b_1, b_2] \\ 0, & \text{muullion} \end{cases}$$

Show the classification results for some values for *a* and *b* ("muullion" means "otherwise").

Answer

Typical cases are presented in the Fig. 2.8.1.

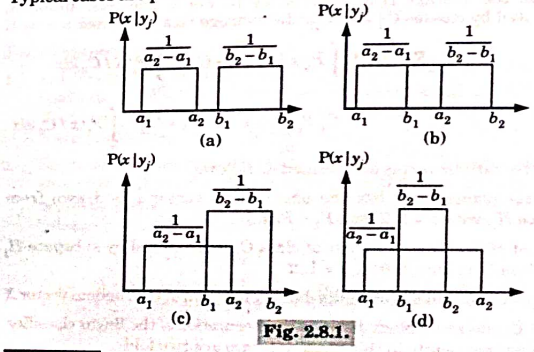


Fig. 2.8.1.

Que 2.9. Define Bayes classifier. Explain how classification is done by using Bayes classifier.

Answer

1. A Bayes classifier is a simple probabilistic classifier based on applying Bayes theorem (from Bayesian statistics) with strong (Naive) independence assumptions.

2. A Naive Bayes classifier assumes that the presence (or absence) of a particular feature of a class is unrelated to the presence (or absence) of any other feature.
3. Depending on the precise nature of the probability model, Naive Bayes classifiers can be trained very efficiently in a supervised learning.
4. In many practical applications, parameter estimation for Naive Bayes models uses the method of maximum likelihood; in other words, one can work with the Naive Bayes model without believing in Bayesian probability or using any Bayesian methods.
5. An advantage of the Naive Bayes classifier is that it requires a small amount of training data to estimate the parameters (means and variances of the variables) necessary for classification.
6. The perceptron bears a certain relationship to a classical pattern classifier known as the Bayes classifier.
7. When the environment is Gaussian, the Bayes classifier reduces to a linear classifier.

   In the Bayes classifier, or Bayes hypothesis testing procedure, we minimize the average risk, denoted by R. For a two-class problem, represented by classes C_1 and C_2, the average risk is defined :

$$R = C_{11}P_1\int_{H_1} P_x(x/C_1)dx + C_{22}P_2\int_{H_2} P_x(x/C_2)dx$$
$$+ C_{21}P_1\int_{H_2} P_x(x/C_1)dx + C_{12}P_2\int_{H_1} P_x(x/C_2)dx$$

   where the various terms are defined as follows :

   P_i = Prior probability that the observation vector x is drawn from subspace H_i, with $i = 1, 2$, and $P_1 + P_2 = 1$

   C_{ij} = Cost of deciding in favour of class C_i represented by subspace H_i when class C_j is true, with $i, j = 1, 2$

   $P_x(x/C_i)$ = Conditional probability density function of the random vector X

8. Fig. 2.9.1(*a*) depicts a block diagram representation of the Bayes classifier. The important points in this block diagram are two fold :
   a. The data processing in designing the Bayes classifier is confined entirely to the computation of the likelihood ratio $\wedge(x)$.
   b. This computation is completely invariant to the values assigned to the prior probabilities and involved in the decision-making process. These quantities merely affect the values of the threshold x.
   c. From a computational point of view, we find it more convenient to work with logarithm of the likelihood ratio rather than the likelihood ratio itself.

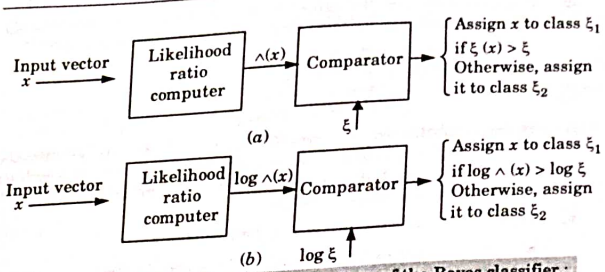


Fig. 2.9.1. Two equivalent implementations of the Bayes classifier : (*a*) Likelihood ratio test, (*b*) Log-likelihood ratio test

Que 2.10. Discuss Bayes classifier using some example in detail.

Answer

Bayes classifier : Refer Q. 2.9, Page 2–8L, Unit-2.

For example :

1. Let D be a training set of features and their associated class labels. Each feature is represented by an n-dimensional attribute vector $X = (x_1, x_2, ..., x_n)$ depicting n measurements made on the feature from n attributes, respectively $A_1, A_2, ..., A_n$.
2. Suppose that there are m classes, $C_1, C_2, ..., C_m$. Given a feature X, the classifier will predict that X belongs to the class having the highest posterior probability, conditioned on X. That is, classifier predicts that X belongs to class C_i if and only if,

$$p(C_i|X) > p(C_j|X) \text{ for } 1 \le j \le m,\ j \ne i$$

   Thus, we maximize $p(C_i|X)$. The class C_i for which $p(C_i|X)$ is maximized is called the maximum posterior hypothesis. By Bayes theorem,

$$p(C_i|X) = \frac{p(X|C_i)p(C_i)}{p(X)}$$

3. As $p(X)$ is constant for all classes, only $P(X|\ C_i)\ P(C_i)$ need to be maximized. If the class prior probabilities are not known then it is commonly assumed that the classes are equally likely *i.e.*, $p(C_1) = p(C_2) = ... p(C_m)$ and therefore $p(X|C_i)$ is maximized. Otherwise $p(X|C_i)\,p(C_i)$ is maximized.
4. i. Given data sets with many attributes, the computation of $p(X|C_i)$ will be extremely expensive.
   ii. To reduce computation in evaluating $p(X|C_i)$, the assumption of class conditional independence is made.

iii. This presumes that the values of the attributes are conditionally independent of one another, given the class label of the feature.

Thus, $p(X|C_i) = \prod_{k=1}^{n} p(x_k|C_i)$

$= p(x_1|C_2) \times p(x_2|C_2)x.... \times p(x_n|C_i)$

iv. The probabilities $p(x_1|C_i), p(x_2|C_i),...., p(x_n|C_i)$ are easily estimated from the training feature. Here x_k refers to the value of attribute A_k for each attribute, it is checked whether the attribute is categorical or continuous valued.

v. For example, to compute $p(X|C_i)$ we consider,

a. If A_k is categorical then $p(x_k|C_i)$ is the number of feature of class C_i in D having the value x_k for A_k divided by $|C_i, D|$, the number of features of class C_i in D.

b. If A_k is continuous valued then continuous valued attribute is typically assumed to have a Gaussian distribution with a mean μ and standard deviation σ, defined by,

$$g(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{\left[\frac{-1(x-\mu)^2}{2 \quad \sigma^2}\right]}$$

so that $p(x_k|C_i) = g(x_k)$.

vi. There is a need to compute the mean μ and the standard deviation σ of the value of attribute A_k for training set of class C_i. These values are used to estimate $p(x_k|C_i)$.

vii. For example, let X = (35, Rs. 40,000) where A_1 and A_2 are the attributes age and income, respectively. Let the class label attribute be buys-computer.

viii. The associated class label for X is yes (*i.e.*, buys-computer = yes). Let's suppose that age has not been discretized and therefore exists as a continuous valued attribute.

ix. Suppose that from the training set, we find that customer in D who buy a computer are 38 ± 12 years of age. In other words, for attribute age and this class, we have $\mu = 38$ and $\sigma = 12$.

5. In order to predict the class label of X, $p(X|C_i)p(C_i)$ is evaluated for each class C_i. The classifier predicts that the class label of X is the class C_i if and only if

$p(X|C_i)\,P(C_i) > p(X|C_j)\,p(C_j)$ for $1 \le j \le m, j \ne i$,

The predicted class label is the class C_i for which $p(X|C_i)\,P(C_i)$ is the maximum.

Que 2.11. Let blue, green, and red be three classes of objects with prior probabilities given by P(blue) = 1/4, P(green) = 1/2, P(red) = 1/4. Let there be three types of objects pencils, pens, and paper. Let the class-conditional probabilities of these objects be given as follows. Use Bayes classifier to classify pencil, pen and paper.

P(pencil/green) = 1/3 P(pen/green) = 1/2 P(paper/green) = 1/6
P(pencil/blue) = 1/2 P(pen/blue) = 1/6 P(paper/blue) = 1/3
P(pencil/red) = 1/6 P(pen/red) = 1/3 P(paper/red) = 1/2

Answer

As per Bayes rule :

$$P(\text{green/pencil}) = \frac{P(\text{pencil/ green})\,P(\text{green})}{(P(\text{pencil/ green})\,P(\text{green}) + P(\text{pencil/ blue})\,P(\text{blue}) + P(\text{pencil/ red})\,P(\text{red})}$$

$$= \frac{\frac{1}{3}\times\frac{1}{2}}{\left(\frac{1}{3}\times\frac{1}{2}+\frac{1}{2}\times\frac{1}{4}+\frac{1}{6}\times\frac{1}{4}\right)} = \frac{\frac{1}{6}}{0.33} = 0.5050$$

$$P(\text{blue/pencil}) = \frac{P(\text{pencil/ blue})\,P(\text{blue})}{(P(\text{pencil/ green})\,P(\text{green}) + P(\text{pencil/ blue})\,P(\text{blue}) + P(\text{pencil/ red})\,P(\text{red})}$$

$$= \frac{\frac{1}{2}\times\frac{1}{4}}{0.33} = 0.378$$

$$P(\text{red/pencil}) = \frac{P(\text{pencil/ red})\,P(\text{red})}{(P(\text{pencil/ red})\,P(\text{red}) + P(\text{pencil/ blue})\,P(\text{blue}) + P(\text{pencil/ green})\,P(\text{green})}$$

$$= \frac{\frac{1}{6}\times\frac{1}{4}}{0.33} = \frac{\frac{1}{24}}{0.33} = 0.126$$

Since, P(green/pencil) has the highest value therefore pencil belongs to class green.

$$P(\text{green/pen}) = \frac{P(\text{pen/ green})\,P(\text{green})}{P(\text{pen/ green})\,P(\text{green}) + P(\text{pen/ blue})\,P(\text{blue}) + P(\text{pen/ red})\,P(\text{red})}$$

$$= \frac{\frac{1}{2}\times\frac{1}{2}}{\frac{1}{2}\times\frac{1}{2}+\frac{1}{6}\times\frac{1}{4}+\frac{1}{3}\times\frac{1}{4}} = \frac{\frac{1}{4}}{0.375} = 0.666$$

$$P(\text{blue/pen}) = \frac{P(\text{pen/ blue})P(\text{blue})}{P(\text{pen/ green})\,P(\text{green}) + P(\text{pen/ blue})\,P(\text{blue}) + P(\text{pen/ red})\,P(\text{red})}$$

$$= \frac{\frac{1}{6} \times \frac{1}{4}}{0.375} = \frac{\frac{1}{24}}{0.375} = 0.111$$

$$P(\text{red/pen}) = \frac{P(\text{pen/ red})\,P(\text{red})}{P(\text{pen/ green})\,P(\text{green}) + P(\text{pen/ blue})\,P(\text{blue}) + P(\text{pen/ red})\,P(\text{red})}$$

$$= \frac{\frac{1}{3} \times \frac{1}{4}}{0.375} = \frac{\frac{1}{12}}{0.375} = 0.222$$

Since P(green/pen) has the highest value therefore, pen belongs to class green.

$$P(\text{green/paper}) = \frac{P(\text{paper/ green})\,P(\text{green})}{P(\text{paper/ green})\,P(\text{green}) + P(\text{paper/ blue})\,P(\text{blue}) + P(\text{paper/ red})\,P(\text{red})}$$

$$= \frac{\frac{1}{6} \times \frac{1}{2}}{\frac{1}{6} \times \frac{1}{2} + \frac{1}{3} \times \frac{1}{4} + \frac{1}{2} \times \frac{1}{4}} = \frac{\frac{1}{12}}{\frac{1}{12} + \frac{1}{12} + \frac{1}{8}}$$

$$= \frac{\frac{1}{12}}{0.291} = 0.286$$

$$P(\text{blue/paper}) = \frac{P(\text{paper/ blue})\,P(\text{blue})}{P(\text{paper/ green})\,P(\text{green}) + P(\text{paper/ blue})\,P(\text{blue}) + P(\text{paper/ red})\,P(\text{red})}$$

$$= \frac{\frac{1}{3} \times \frac{1}{4}}{0.291} = \frac{\frac{1}{12}}{0.291} = 0.286$$

$$P(\text{red/paper}) = \frac{P(\text{paper/ red})\,P(\text{red})}{P(\text{paper/ green})\,P(\text{green}) + P(\text{paper/ blue})\,P(\text{blue}) + P(\text{paper/ red})\,P(\text{red})}$$

$$= \frac{\frac{1}{2} \times \frac{1}{4}}{0.291} = \frac{\frac{1}{8}}{0.291} = 0.429$$

Since, P(red/paper) has the highest value therefore, paper belongs to class red.

Que 2.12. Explain Naive Bayes classifier.

Answer

1. Naive Bayes model is the most common Bayesian network model used in machine learning.
2. Here, the class variable C is the root which is to be predicted and the attribute variables X_i are the leaves.
3. The model is Naive because it assumes that the attributes are conditionally independent of each other, given the class.

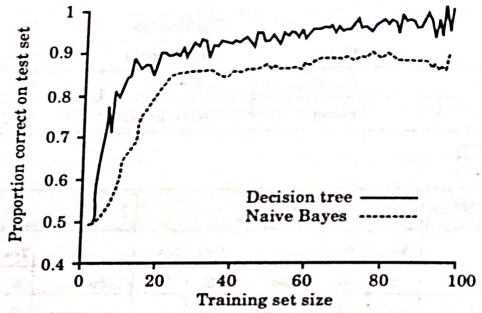


Fig. 2.12.1. The learning curve for Naive Bayes learning.

4. Assuming Boolean variables, the parameters are :

$$\theta = P(C = \text{true}),\ \theta_{i1} = P(X_i = \text{true} \mid C = \text{true}),$$

$$\theta_{i2} = P(X_i = \text{true} \mid C = \text{False})$$

5. Naive Bayes models can be viewed as Bayesian networks in which each X_i has C as the sole parent and C has no parents.
6. A Naive Bayes model with gaussian $P(X_i \mid C)$ is equivalent to a mixture of gaussians with diagonal covariance matrices.
7. While mixtures of gaussians are used for density estimation in continuous domains, Naive Bayes models used in discrete and mixed domains.
8. Naive Bayes models allow for very efficient inference of marginal and conditional distributions.
9. Naive Bayes learning has no difficulty with noisy data and can give more appropriate probabilistic predictions.

Que 2.13. Consider a two-class (Tasty or non-Tasty) problem with the following training data. Use Naive Bayes classifier to classify the pattern :
"Cook = Asha, Health-Status = Bad, Cuisine = Continental".

Cook	Health-Status	Cuisine	Tasty
Asha	Bad	Indian	Yes
Asha	Good	Continental	Yes
Sita	Bad	Indian	No
Sita	Good	Indian	Yes
Usha	Bad	Indian	Yes
Usha	Bad	Continental	No
Sita	Bad	Continental	No
Sita	Good	Continental	Yes
Usha	Good	Indian	Yes
Usha	Good	Continental	No

Answer

Cook			Health-status			Cuisine		
	Yes	No		Yes	No		Yes	No
Asha	2	0	Bad	2	3	Indian	4	1
Sita	2	2	Good	4	1	Continental	2	3
Usha	2	2						

Tasty	
Yes	No
6	4

Cook			Health-status			Cuisine		
	Yes	No		Yes	No		Yes	No
Asha	2/6	0	Bad	2/6	3/4	Indian	4/6	1/4
Sita	2/6	2/4	Good	4/6	1/4	Continental	2/6	3/4
Usha	2/6	2/4						

Tasty	
Yes	No
6/10	4/10

Likelihood of yes = $\frac{2}{6} \times \frac{2}{6} \times \frac{2}{6} \times \frac{6}{10} = 0.023$

Likelihood of no = $0 \times \frac{3}{4} \times \frac{3}{4} \times \frac{4}{10} = 0$

Therefore, the prediction is tasty.

Que 2.14. Explain EM algorithm with steps.

Answer

1. The Expectation-Maximization (EM) algorithm is an iterative way to find maximum-likelihood estimates for model parameters when the data is incomplete or has missing data points or has some hidden variables.
2. EM chooses random values for the missing data points and estimates a new set of data.
3. These new values are then recursively used to estimate a better first data, by filling up missing points, until the values get fixed.
4. These are the two basic steps of the EM algorithm :
   - **a. Estimation Step :**
     - i. Initialize μ_k, Σ_k and π_k by random values, or by K means clustering results or by hierarchical clustering results.
     - ii. Then for those given parameter values, estimate the value of the latent variables (*i.e.*, γ_k).
   - **b. Maximization Step :** Update the value of the parameters (*i.e.*, μ_k, Σ_k and π_k) calculated using ML method :
     - i. Initialize the mean μ_k, the covariance matrix Σ_k and the mixing coefficients π_k by random values, (or other values).
     - ii. Compute the π_k values for all k.
     - iii. Again estimate all the parameters using the current π_k values.
     - iv. Compute log-likelihood function.
     - v. Put some convergence criterion.
     - vi. If the log-likelihood value converges to some value (or if all the parameters converge to some values) then stop, else return to Step 2.

Que 2.15. **Describe the usage, advantages and disadvantages of EM algorithm.**

Answer

Usage of EM algorithm :

1. It can be used to fill the missing data in a sample.
2. It can be used as the basis of unsupervised learning of clusters.
3. It can be used for the purpose of estimating the parameters of Hidden Markov Model (HMM).
4. It can be used for discovering the values of latent variables.

Advantages of EM algorithm are :

1. It is always guaranteed that likelihood will increase with each iteration.
2. The E-step and M-step are often pretty easy for many problems in terms of implementation.
3. Solutions to the M-steps often exist in the closed form.

Disadvantages of EM algorithm are :

1. It has slow convergence.
2. It makes convergence to the local optima only.
3. It requires both the probabilities, forward and backward (numerical optimization requires only forward probability).

Que 2.16. **Write a short note on Bayesian network.**

OR

Explain Bayesian network by taking an example. How is the Bayesian network powerful representation for uncertainty knowledge ?

Answer

1. A Bayesian network is a directed acyclic graph in which each node is annotated with quantitative probability information.
2. The full specification is as follows :
   i. A set of random variables makes up the nodes of the network variables may be discrete or continuous.
   ii. A set of directed links or arrows connects pairs of nodes. If there is an arrow from x to node y, x is said to be a parent of y.
   iii. Each node x_i has a conditional probability distribution $P(x_i \mid \text{parent}(x_i))$ that quantifies the effect of parents on the node.
   iv. The graph has no directed cycles (and hence is a directed acyclic graph or DAG).

3. A Bayesian network provides a complete description of the domain. Every entry in the full joint probability distribution can be calculated from the information in the network.
4. Bayesian networks provide a concise way to represent conditional independence relationships in the domain.
5. A Bayesian network is often exponentially smaller than the full joint distribution.

For example :

1. Suppose we want to determine the possibility of grass getting wet or dry due to the occurrence of different seasons.
2. The weather has three states : Sunny, Cloudy, and Rainy. There are two possibilities for the grass : Wet or Dry.
3. The sprinkler can be on or off. If it is rainy, the grass gets wet but if it is sunny, we can make grass wet by pouring water from a sprinkler.
4. Suppose that the grass is wet. This could be contributed by one of the two reasons - Firstly, it is raining. Secondly, the sprinklers are turned on.
5. Using the Baye's rule, we can deduce the most contributing factor towards the wet grass.

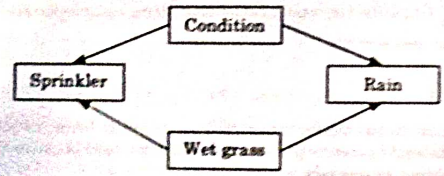


Fig. 2.16.1.

Bayesian network possesses the following merits in uncertainty knowledge representation :

1. Bayesian network can conveniently handle incomplete data.
2. Bayesian network can learn the casual relation of variables. In data analysis, casual relation is helpful for field knowledge understanding, it can also easily lead to precise prediction even under much interference.
3. The combination of bayesian network and bayesian statistics can take full advantage of field knowledge and information from data.
4. The combination of bayesian network and other models can effectively avoid over-fitting problem.

Que 2.17. Explain the role of prior probability and posterior probability in bayesian classification.

Answer

Role of prior probability :

1. The prior probability is used to compute the probability of the event before the collection of new data.
2. It is used to capture our assumptions / domain knowledge and is independent of the data.
3. It is the unconditional probability that is assigned before any relevant evidence is taken into account.

Role of posterior probability :

1. Posterior probability is used to compute the probability of an event after collection of data.
2. It is used to capture both the assumptions / domain knowledge and the pattern in observed data.
3. It is the conditional probability that is assigned after the relevant evidence or background is taken into account.

Que 2.18. Explain the method of handling approximate inference in Bayesian networks.

Answer

1. Approximate inference methods can be used when exact inference methods lead to unacceptable computation times because the network is very large or densely connected.
2. Methods handling approximate inference :
   - i. **Simulation methods :** This method use the network to generate samples from the conditional probability distribution and estimate conditional probabilities of interest when the number of samples is sufficiently large.
   - ii. **Variational methods :** This method express the inference task as a numerical optimization problem and then find upper and lower bounds of the probabilities of interest by solving a simplified version of this optimization problem.

PART-3

Support Vector Machine, Introduction, Types of Support Vector Kernel - (Linear Kernel Polynomial Kernel, and Gaussian Kernel), Hyperplane : (Decision Surface), Properties of SVM, and Issues in SVM.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.19. Write short note on support vector machine.

Answer

Refer Q. 1.23, Page 1–23L, Unit-1.

Que 2.20. What are the types of support vector machine ?

Answer

Following are the types of support vector machine :

1. **Linear SVM :** Linear SVM is used for linearly separable data, which means if a dataset can be classified into two classes by using a single straight line, then such data is termed as linearly separable data, and classifier is used called as Linear SVM classifier.
2. **Non-linear SVM :** Non-Linear SVM is used for non-linearly separated data, which means if a dataset cannot be classified by using a straight line, then such data is termed as non-linear data and classifier used is called as Non-linear SVM classifier.

Que 2.21. What is polynomial kernel ? Explain polynomial kernel using one dimensional and two dimensional.

Answer

1. The polynomial kernel is a kernel function used with Support Vector Machines (SVMs) and other kernelized models, that represents the

similarity of vectors (training samples) in a feature space over polynomials of the original variables, allowing learning of non-linear models.

2. Polynomial kernel function is given by the equation :

$$(a \times b + r)^d$$

where, a and b are two different data points that we need to classify.

r determines the coefficients of the polynomial.

d determines the degree of the polynomial.

3. We perform the dot products of the data points, which gives us the high dimensional coordinates for the data.
4. When $d = 1$, the polynomial kernel computes the relationship between each pair of observations in 1-Dimension and these relationships help to find the support vector classifier.
5. When $d = 2$, the polynomial kernel computes the 2-Dimensional relationship between each pair of observations which help to find the support vector classifier.

Que 2.22. Describe Gaussian Kernel (Radial Basis Function).

Answer

1. RBF kernel is a function whose value depends on the distance from the origin or from some point.
2. Gaussian Kernel is of the following format :

$$K(X_1, X_2,) = \text{exponent } (-\gamma \| X_1 - X_2 \|^2)$$

$\| X_1 - X_2 \|$ = Euclidean distance between X_1 and X_2

Using the distance in the original space we calculate the dot product (similarity) of X_1 and X_2.

3. Following are the parameters used in Gaussain Kernel:

a. **C :** Inverse of the strength of regularization.

Behavior : As the value of 'c' increases the model gets overfits.

As the value of 'c' decreases the model underfits.

b. **γ :** Gamma (used only for RBF kernel)

Behavior : As the value of 'γ' increases the model gets overfits.

As the value of 'γ' decreases the model underfits.

Que 2.23. Write short note on hyperplane (Decision surface).

Answer

1. A hyperplane in an n-dimensional Euclidean space is a flat, n-1 dimensional subset of that space that divides the space into two disconnected parts.
2. For example let's assume a line to be one dimensional Euclidean space.
3. Now pick a point on the line, this point divides the line into two parts.
4. The line has 1 dimension, while the point has 0 dimensions. So a point is a hyperplane of the line.
5. For two dimensions we saw that the separating line was the hyperplane.
6. Similarly, for three dimensions a plane with two dimensions divides the 3d space into two parts and thus act as a hyperplane.
7. Thus for a space of n dimensions we have a hyperplane of n-1 dimensions separating it into two parts.

Que 2.24. What are the advantages and disadvantags of SVM ?

Answer

Advantages of SVM are :

1. **Guaranteed optimality :** Owing to the nature of Convex Optimization, the solution will always be global minimum, not a local minimum.
2. **The abundance of implementations :** We can access it conveniently.
3. SVM can be used for linearly separable as well as non-linearly separable data. Linearly separable data pases hard margin whereas non-linearly separable data poses a soft margin.
4. SVMs provide compliance to the semi-supervised learning models. It can be used in areas where the data is labeled as well as unlabeled. It only requires a condition to the minimization problem which is known as the transductive SVM.
5. Feature Mapping used to be quite a load on the computational complexity of the overall training performance of the model. However, with the help of Kernel Trick, SVM can carry out the feature mapping using the simple dot product.

Disadvantages of SVM :

1. SVM does not give the best performance for handling text structures as compared to other algorithms that are used in handling text data. This leads to loss of sequential information and thereby, leading to worse performance.

2. SVM cannot return the probabilistic confidence value that is similar to logistic regression. This does not provide much explanation as the confidence of prediction is important in several applications.
3. The choice of the kernel is perhaps the biggest limitation of the support vector machine. Considering so many kernels present, it becomes difficult to choose the right one for the data.

Que 2.25. Explain the properties of SVM.

Answer

Following are the properties of SVM :

1. **Flexibility in choosing a similarity function :** Sparseness of solution when dealing with large data sets only support vectors are used to specify the separating hyperplane
2. **Ability to handle large feature spaces :** complexity does not depend on the dimensionality of the feature space
3. **Overfitting can be controlled by soft margin approach :** A simple convex optimization problem which is guaranteed to converge to a single global solution

Que 2.26. What are the parameters used in support vector classifier ?

Answer

Parameters used in support vector classifier are :

1. **Kernel :**
   a. Kernel, is selected based on the type of data and also the type of transformation.
   b. By default, the kernel is Radial Basis Function Kernel (RBF).
2. **Gamma :**
   a. This parameter decides how far the influence of a single training example reaches during transformation, which in turn affects how tightly the decision boundaries end up surrounding points in the input space.
   b. If there is a small value of gamma, points farther apart are considered similar.
   c. So, more points are grouped together and have smoother decision boundaries (may be less accurate).
   d. Larger values of gamma cause points to be closer together (may cause overfitting).

3. **The 'C' parameter :**
   a. This parameter controls the amount of regularization applied on the data.
   b. Large values of C mean low regularization which in turn causes the training data to fit very well (may cause overfitting).
   c. Lower values of C mean higher regularization which causes the model to be more tolerant of errors (may lead to lower accuracy).

☺☺☺

3 UNIT

Decision Tree Learning

CONTENTS

PART-1

Decision Tree Learning, Decision Tree Learning Algorithm, Inductive Bias, Inductive Inference with Decision Trees.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.1. **Describe the basic terminology used in decision tree.**

Answer

Basic terminology used in decision trees are :

1. **Root node :** It represents entire population or sample and this further gets divided into two or more homogeneous sets.
2. **Splitting :** It is a process of dividing a node into two or more sub-nodes.
3. **Decision node :** When a sub-node splits into further sub-nodes, then it is called decision node.

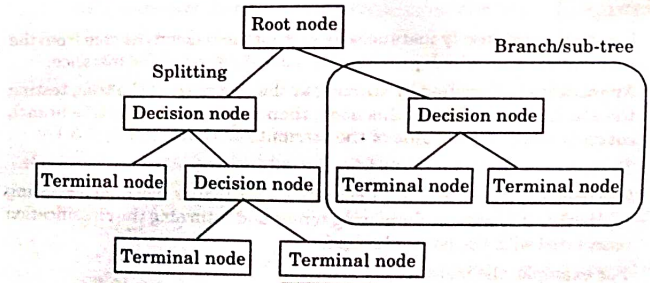


Fig. 3.1.1.

4. **Leaf / Terminal node :** Nodes that do not split is called leaf or terminal node.
5. **Pruning :** When we remove sub-nodes of a decision node, this process is called pruning. This process is opposite to splitting process.
6. **Branch / sub-tree :** A sub section of entire tree is called branch or sub-tree.
7. **Parent and child node :** A node which is divided into sub-nodes is called parent node of sub-nodes where as sub-nodes are the child of parent node.

Que 3.2. **Why do we use decision tree ?**

Answer

1. Decision trees can be visualized, simple to understand and interpret.
2. They require less data preparation whereas other techniques often require data normalization, the creation of dummy variables and removal of blank values.
3. The cost of using the tree (for predicting data) is logarithmic in the number of data points used to train the tree.
4. Decision trees can handle both categorical and numerical data whereas other techniques are specialized for only one type of variable.
5. Decision trees can handle multi-output problems.
6. Decision tree is a white box model *i.e.*, the explanation for the condition can be explained easily by Boolean logic because there are two outputs, For example yes or no.
7. Decision trees can be used even if assumptions are violated by the dataset from which the data is taken.

Que 3.3. **How can we express decision trees ?**

Answer

1. Decision trees classify instances by sorting them down the tree from the root to leaf node, which provides the classification of the instance.
2. An instance is classified by starting at the root node of the tree, testing the attribute specified by this node, then moving down the tree branch corresponding to the value of the attribute as shown in Fig. 3.3.1.
3. This process is then repeated for the subtree rooted at the new node.
4. The decision tree in Fig. 3.3.1 classifies a particular morning according to whether it is suitable for playing tennis and returning the classification associated with the particular leaf.
5. For example, the instance

   (Outlook = Rain, Temperature = Hot, Humidity = High, Wind = Strong)

   would be sorted down the left most branch of this decision tree and would therefore be classified as a negative instance.
6. In other words, decision tree represent a disjunction of conjunctions of constraints on the attribute values of instances.

   (Outlook = Sunny $\wedge$ Humidity = Normal) $\vee$ (Outlook = Overcast) $\vee$ (Outlook = Rain $\wedge$ Wind = Weak)

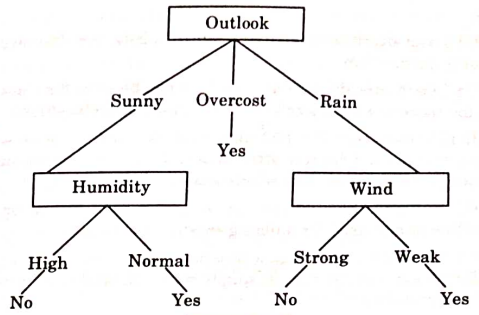


Fig. 3.3.1.

Que 3.4. **Explain various decision tree learning algorithms.**

Answer

Various decision tree learning algorithms are :

1. **ID3 (Iterative Dichotomiser 3) :**
   - i. ID3 is an algorithm used to generate a decision tree from a dataset.
   - ii. To construct a decision tree, ID3 uses a top-down, greedy search through the given sets, where each attribute at every tree node is tested to select the attribute that is best for classification of a given set.
   - iii. Therefore, the attribute with the highest information gain can be selected as the test attribute of the current node.
   - iv. In this algorithm, small decision trees are preferred over the larger ones. It is a heuristic algorithm because it does not construct the smallest tree.
   - v. For building a decision tree model, ID3 only accepts categorical attributes. Accurate results are not given by ID3 when there is noise and when it is serially implemented.
   - vi. Therefore data is preprocessed before constructing a decision tree.
   - vii. For constructing a decision tree information gain is calculated for each and every attribute and attribute with the highest information gain becomes the root node. The rest possible values are denoted by arcs.
   - viii. All the outcome instances that are possible are examined whether they belong to the same class or not. For the instances of the same class, a single name is used to denote the class otherwise the instances are classified on the basis of splitting attribute.

2. **C4.5 :**
   i. C4.5 is an algorithm used to generate a decision tree. It is an extension of ID3 algorithm.
   ii. C4.5 generates decision trees which can be used for classification and therefore C4.5 is referred to as statistical classifier.
   iii. It is better than the ID3 algorithm because it deals with both continuous and discrete attributes and also with the missing values and pruning trees after construction.
   iv. C5.0 is the commercial successor of C4.5 because it is faster, memory efficient and used for building smaller decision trees.
   v. C4.5 performs by default a tree pruning process. This leads to the formation of smaller trees, simple rules and produces more intuitive interpretations.

3. **CART (Classification And Regression Trees) :**
   i. CART algorithm builds both classification and regression trees.
   ii. The classification tree is constructed by CART through binary splitting of the attribute.
   iii. Gini Index is used for selecting the splitting attribute.
   iv. The CART is also used for regression analysis with the help of regression tree.
   v. The regression feature of CART can be used in forecasting a dependent variable given a set of predictor variable over a given period of time.
   vi. CART has an average speed of processing and supports both continuous and nominal attribute data.

Que 3.5. **What are the advantages and disadvantages of different decision tree learning algorithm ?**

Answer

Advantages of ID3 algorithm :

1. *The training data is used to create understandable prediction rules.*
2. *It builds short and fast tree.*
3. *ID3 searches the whole dataset to create the whole tree.*
4. *It finds the leaf nodes thus enabling the test data to be pruned and reducing the number of tests.*
5. *The calculation time of ID3 is the linear function of the product of the characteristic number and node number.*

Disadvantages of ID3 algorithm :

1. *For a small sample, data may be overfitted or overclassified.*

2. For making a decision, only one attribute is tested at an instant thus consuming a lot of time.
3. Classifying the continuous data may prove to be expensive in terms of computation, as many trees have to be generated to see where to break the continuous sequence.
4. It is overly sensitive to features when given a large number of input values.

Advantages of C4.5 algorithm :

1. C4.5 is easy to implement.
2. C4.5 builds models that can be easily interpreted.
3. It can handle both categorical and continuous values.
4. It can deal with noise and missing value attributes.

Disadvantages of C4.5 algorithm :

1. A small variation in data can lead to different decision trees when using C4.5.
2. For a small training set, C4.5 does not work very well.

Advantages of CART algorithm :

1. CART can handle missing values automatically using proxy splits.
2. It uses combination of continuous/discrete variables.
3. CART automatically performs variable selection.
4. CART can establish interactions among variables.
5. CART does not vary according to the monotonic transformation of predictive variable.

Disadvantages of CART algorithm :

1. CART has unstable decision trees.
2. CART splits only by one variable.
3. It is non-parametric algorithm.

PART-2

Entropy and Information Theory, Information Gain, ID-3 Algorithm, Issues in Decision Tree Learning.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.6. **Explain attribute selection measures used in decision tree.**

Answer

Attribute selection measures used in decision tree are :

1. **Entropy :**
   i. Entropy is a measure of uncertainty associated with a random variable.
   ii. The entropy increases with the increase in uncertainty or randomness and decreases with a decrease in uncertainty or randomness.
   iii. The value of entropy ranges from 0-1.

$$\text{Entropy}(D) = \sum_{i=1}^{c} - p_i \log_2(p_i)$$

   where p_i is the non-zero probability that an arbitrary tuple in D belongs to class C and is estimated by $|C_i, D|/|D|$.
   iv. A log function of base 2 is used because the entropy is encoded in bits 0 and 1.
2. **Information gain :**
   i. ID3 uses information gain as its attribute selection measure.
   ii. Information gain is the difference between the original information gain requirement (*i.e.* based on the proportion of classes) and the new requirement (*i.e.* obtained after the partitioning of A).

$$\text{Gain}(D, A) = \text{Entropy}(D) - \sum_{j=1}^{v} \frac{|D_j|}{|D|} \text{Entropy}(D_j)$$

   Where,

   D : A given data partition

   A : Attribute

   V : Suppose we partition the tuples in D on some attribute A having V distinct values

   iii. D is split into V partition or subsets, $\{D_1, D_2, ..D_j\}$ where D_j contains those tuples in D that have outcome a_j, of A.
   iv. The attribute that has the highest information gain is chosen.
3. **Gain ratio :**
   i. The information gain measure is biased towards tests with many outcomes.
   ii. That is, it prefers to select attributes having a large number of values.
   iii. As each partition is pure, the information gain by partitioning is maximal. But such partitioning cannot be used for classification.
   iv. C4.5 uses this attribute selection measure which is an extension to the information gain.

   v. Gain ratio differs from information gain, which measures the information with respect to a classification that is acquired based on some partitioning.
   vi. Gain ratio applies kind of information gain using a split information value defined as :

$$\text{SplitInfo}_A = - \sum_{j=1}^{v} \frac{|D_j|}{|D|} \log_2 \left(\frac{|D_j|}{|D|} \right)$$

   vii. The gain ratio is then defined as :

$$\text{Gain ratio } (A) = \frac{\text{Gain } (A)}{\text{SplitInfo}_A (D)}$$

   viii. A splitting attribute is selected which is the attribute having the maximum gain ratio.

Que 3.7. Explain applications of decision tree in various areas of data mining.

Answer

The various decision tree applications in data mining are :

1. **E-Commerce :** It is used widely in the field of e-commerce, decision tree helps to generate online catalog which is an important factor for the success of an e-commerce website.
2. **Industry :** Decision tree algorithm is useful for producing quality control (faults identification) systems.
3. **Intelligent vehicles :** An important task for the development of intelligent vehicles is to find the lane boundaries of the road.
4. **Medicine :**
   a. Decision tree is an important technique for medical research and practice. A decision tree is used for diagnostic of various diseases.
   b. Decision tree is also used for hard sound diagnosis.
5. **Business :** Decision trees find use in the field of business where they are used for visualization of probabilistic business models, used in CRM (Customer Relationship Management) and used for credit scoring for credit card users and for predicting loan risks in banks.

Que 3.8. Explain procedure of ID3 algorithm.

Answer

ID3 (Examples, Target Attribute, Attributes) :

1. Create a Root node for the tree.
2. If all Examples are positive, return the single-node tree root, with label = +

3. If all Examples are negative, return the single-node tree root, with label = –
4. If Attributes is empty, return the single-node tree root, with label = most common value of target attribute in examples.
5. Otherwise begin
   a. $A \leftarrow$ the attribute from Attributes that best classifies Examples
   b. The decision attribute for Root $\leftarrow A$
   c. For each possible value, V_i, of A,
      i. Add a new tree branch below root, corresponding to the test $A = V_i$
      ii. Let Example V_i be the subset of Examples that have value V_i for A
      iii. If Example V_i is empty
         a. Then below this new branch add a leaf node with label = most common value of TargetAttribute in Examples
         b. Else below this new branch add the sub-tree ID3 (Example V_i, TargetAttribute, Attributes–{A})
6. End
7. Return root.

Que 3.9. Explain inductive bias with inductive system.

Answer

Inductive bias :

1. Inductive bias refers to the restrictions that are imposed by the assumptions made in the learning method.
2. For example, assuming that the solution to the problem of road safety can be expressed as a conjunction of a set of eight concepts.
3. This does not allow for more complex expressions that cannot be expressed as a conjunction.
4. This inductive bias means that there are some potential solutions that we cannot explore, and not contained within the version space we examine.
5. Order to have an unbiased learner, the version space would have to contain every possible hypothesis that could possibly be expressed.
6. The solution that the learner produced could never be more general than the complete set of training data.
7. In other words, it would be able to classify data that it had previously seen (as the rote learner could) but would be unable to generalize in order to classify new, unseen data.

8. The inductive bias of the candidate elimination algorithm is that it is only able to classify a new piece of data if all the hypotheses contained within its version space give data the same classification.
9. Hence, the inductive bias does impose a limitation on the learning method.

Inductive system :

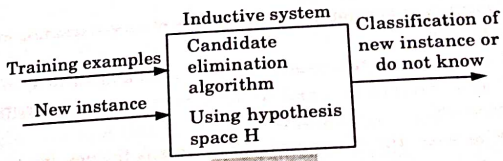


Fig. 3.9.1.

Que 3.10. Explain inductive learning algorithm.

Answer

Inductive learning algorithm :

Step 1 : Divide the table '*T*' containing *m* examples into *n* sub-tables (*t*1, *t*2, ... *tn*). One table for each possible value of the class attribute (repeat steps 2-8 for each sub-table).

Step 2 : Initialize the attribute combination count *j* = 1.

Step 3 : For the sub-table on which work is going on, divide the attribute list into distinct combinations, each combination with *j* distinct attributes.

Step 4 : For each combination of attributes, count the number of occurrences of attribute values that appear under the same combination of attributes in unmarked rows of the sub-table under consideration, and at the same time, not appears under the same combination of attributes of other sub-tables. Call the first combination with the maximum number of occurrences the max-combination MAX.

Step 5 : If MAX = = null, increase *j* by 1 and go to Step 3.

Step 6 : Mark all rows of the sub-table where working, in which the values of MAX appear, as classified.

Step 7 : Add a rule (IF attribute = "XYZ" → THEN decision is YES/NO) to R (rule set) whose left-hand side will have attribute names of the MAX with their values separated by AND, and its right hand side contains the decision attribute value associated with the sub-table.

Step 8 : If all rows are marked as classified, then move on to process another sub-table and go to Step 2, else, go to Step 4. If no sub-tables are available, exit with the set of rules obtained till then.

Que 3.11. Which learning algorithms are used in inductive bias ?

Answer

Learning algorithm used in inductive bias are :

1. **Rote-learner :**
   a. Learning corresponds to storing each observed training example in memory.
   b. Subsequent instances are classified by looking them up in memory.
   c. If the instance is found in memory, the stored classification is returned.
   d. Otherwise, the system refuses to classify the new instance.
   e. **Inductive bias :** There is no inductive bias.
2. **Candidate-elimination :**
   a. New instances are classified only in the case where all members of the current version space agree on the classification.
   b. Otherwise, the system refuses to classify the new, instance.
   c. **Inductive bias :** The target concept can be represented in its hypothesis space.
3. **FIND-S :**
   a. This algorithm, finds the most specific hypothesis consistent with the training examples.
   b. It then uses this hypothesis to classify all subsequent instances.
   c. **Inductive bias :** The target concept can be represented in its hypothesis space, and all instances are negative instances unless the opposite is entailed by its other knowledge.

Que 3.12. Discuss the issues related to the applications of decision trees.

Answer

Issues related to the applications of decision trees are :

1. **Missing data :**
   a. When values have gone unrecorded, or they might be too expensive to obtain.
   b. Two problems arise :
      i. To classify an object that is missing from the test attributes.
      ii. To modify the information gain formula when examples have unknown values for the attribute.

2. **Multi-valued attributes :**
   a. When an attribute has many possible values, the information gain measure gives an inappropriate indication of the attribute's usefulness.
   b. In the extreme case, we could use an attribute that has a different value for every example.
   c. Then each subset of examples would be a singleton with a unique classification, so the information gain measure would have its highest value for this attribute, the attribute could be irrelevant or useless.
   d. One solution is to use the gain ratio.
3. **Continuous and integer valued input attributes :**
   a. Height and weight have an infinite set of possible values.
   b. Rather than generating infinitely many branches, decision tree learning algorithms find the split point that gives the highest information gain.
   c. Efficient dynamic programming methods exist for finding good split points, but it is still the most expensive part of real world decision tree learning applications.
4. **Continuous-valued output attributes :**
   a. If we are trying to predict a numerical value, such as the price of a work of art, rather than discrete classifications, then we need a regression tree.
   b. Such a tree has a linear function of some subset of numerical attributes, rather than a single value at each leaf.
   c. The learning algorithm must decide when to stop splitting and begin applying linear regression using the remaining attributes.

PART-3

Instance-based Learning.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.13. Write short note on instance-based learning.

Answer

1. Instance-Based Learning (IBL) is an extension of nearest neighbour or K-NN classification algorithms.
2. IBL algorithms do not maintain a set of abstractions of model created from the instances.
3. The K-NN algorithms have large space requirement.
4. They also extend it with a significance test to work with noisy instances, since a lot of real-life datasets have training instances and K-NN algorithms do not work well with noise.
5. Instance-based learning is based on the memorization of the dataset.
6. The number of parameters is unbounded and grows with the size of the data.
7. The classification is obtained through memorized examples.
8. The cost of the learning process is 0, all the cost is in the computation of the prediction.
9. This kind learning is also known as lazy learning.

Que 3.14. Explain instance-based learning representation.

Answer

Following are the instance based learning representation :

Instance-based representation (1) :

1. The simplest form of learning is plain memorization.
2. This is a completely different way of representing the knowledge extracted from a set of instances : just store the instances themselves and operate by relating new instances whose class is unknown to existing ones whose class is known.
3. Instead of creating rules, work directly from the examples themselves.

Instance-based representation (2) :

1. Instance-based learning is lazy, deferring the real work as long as possible.
2. In instance-based learning, each new instance is compared with existing ones using a distance metric, and the closest existing instance is used to assign the class to the new one. This is also called the nearest-neighbour classification method.
3. Sometimes more than one nearest neighbour is used, and the majority class of the closest k-nearest neighbours is assigned to the new instance. This is termed the k-nearest neighbour method.

Instance-based representation (3) :

1. When computing the distance between two examples, the standard Euclidean distance may be used.

2. A distance of 0 is assigned if the values are identical, otherwise the distance is 1.
3. Some attributes will be more important than others. We need some kinds of attribute weighting. To get suitable attribute weights from the training set is a key problem.
4. It may not be necessary, or desirable, to store all the training instances.

Instance-based representation (4) :

1. Generally some regions of attribute space are more stable with regard to class than others, and just a few examples are needed inside stable regions.
2. An apparent drawback to instance-based representation is that they do not make explicit the structures that are learned.

(a) (b) (c)

Fig. 3.14.1.

Que 3.15. What are the performance dimensions used for instance-based learning algorithm ?

Answer

Performance dimension used for instance-based learning algorithm are :

1. **Generality :**
   a. This is the class of concepts that describe the representation of an algorithm.
   b. IBL algorithms can pac-learn any concept whose boundary is a union of a finite number of closed hyper-curves of finite size.
2. **Accuracy :** This concept describes the accuracy of classification.
3. **Learning rate :**
   a. This is the speed at which classification accuracy increases during training.
   b. It is a more useful indicator of the performance of the learning algorithm than accuracy for finite-sized training sets.
4. **Incorporation costs :**
   a. These are incurred while updating the concept descriptions with a single training instance.
   b. They include classification costs.

5. **Storage requirement :** This is the size of the concept description for IBL algorithms, which is defined as the number of saved instances used for classification decisions.

Que 3.16. **What are the functions of instance-based learning ?**

Answer

Functions of instance-based learning are :

1. **Similarity function :**
   a. This computes the similarity between a training instance i and the instances in the concept description.
   b. Similarities are numeric-valued.
2. **Classification function :**
   a. This receives the similarity function's results and the classification performance records of the instances in the concept description.
   b. It yields a classification for i.
3. **Concept description updater :**
   a. This maintains records on classification performance and decides which instances to include in the concept description.
   b. Inputs include i, the similarity results, the classification results, and a current concept description. It yields the modified concept description.

Que 3.17. **What are the advantages and disadvantages of instance-based learning ?**

Answer

Advantages of instance-based learning :

1. Learning is trivial.
2. Works efficiently.
3. Noise resistant.
4. Rich representation, arbitrary decision surfaces.
5. Easy to understand.

Disadvantages of instance-based learning :

1. Need lots of data.
2. Computational cost is high.
3. Restricted to $x \in R^n$.
4. Implicit weights of attributes (need normalization).
5. Need large space for storage *i.e.*, require large memory.
6. Expensive application time.

PART-4

K-Nearest Neighbour Learning, Locally Weighted Regression, Radial Basis Function Networks.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.18. **Describe *K*-Nearest Neighbour algorithm with steps.**

Answer

1. The *K*NN classification algorithm is used to decide the new instance should belong to which class.
2. When $K = 1$, we have the nearest neighbour algorithm.
3. *K*NN classification is incremental.
4. *K*NN classification does not have a training phase, all instances are stored. Training uses indexing to find neighbours quickly.
5. During testing, *K*NN classification algorithm has to find *K*-nearest neighbours of a new instance. This is time consuming if we do exhaustive comparison.
6. K-nearest neighbours use the local neighborhood to obtain a prediction.

Algorithm : Let m be the number of training data samples. Let p be an unknown point.

1. Store the training samples in an array of data points array. This means each element of this array represents a tuple (x, y).
2. For $i = 0$ to m :
   Calculate Euclidean distance $d(\text{arr}[i], p)$.
3. Make set S of K smallest distances obtained. Each of these distances corresponds to an already classified data point.
4. Return the majority label among S.

Que 3.19. **What are the advantages and disadvantages of *K*-nearest neighbour algorithm ?**

Answer

Advantages of KNN algorithm :

1. **No training period :**
   a. KNN is called lazy learner (Instance-based learning).

b. It does not learn anything in the training period. It does not derive any discriminative function from the training data.

c. In other words, there is no training period for it. It stores the training dataset and learns from it only at the time of making real time predictions.

d. This makes the KNN algorithm much faster than other algorithms that require training for example, SVM, Linear Regression etc.

2. Since the KNN algorithm requires no training before making predictions, new data can be added seamlessly which will not impact the accuracy of the algorithm.

3. KNN is very easy to implement. There are only two parameters required to implement KNN *i.e.*, the value of K and the distance function (for example, Euclidean).

Disadvantages of KNN :

1. **Does not work well with large dataset :** In large datasets, the cost of calculating the distance between the new point and each existing points is huge which degrades the performance of the algorithm.
2. **Does not work well with high dimensions :** The KNN algorithm does not work well with high dimensional data because with large number of dimensions, it becomes difficult for the algorithm to calculate the distance in each dimension.
3. **Need feature scaling :** We need to do feature scaling (standardization and normalization) before applying KNN algorithm to any dataset. If we do not do so, KNN may generate wrong predictions.
4. **Sensitive to noisy data, missing values and outliers :** KNN is sensitive to noise in the dataset. We need to manually represent missing values and remove outliers.

Que 3.20. Explain locally weighted regression.

Answer

1. Model-based methods, such as neural networks and the mixture of Gaussians, use the data to build a parameterized model.
2. After training, the model is used for predictions and the data are generally discarded.
3. In contrast, memory-based methods are non-parametric approaches that explicitly retain the training data, and use it each time a prediction needs to be made.
4. **Locally Weighted Regression (LWR)** is a memory-based method that performs a regression around a point using only training data that are local to that point.
5. LWR was suitable for real-time control by constructing an LWR-based system that learned a difficult juggling task.

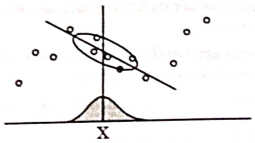


Fig. 3.20.1.

6. The LOESS (Locally Estimated Scatterplot Smoothing) model performs a linear regression on points in the data set, weighted by a kernel centered at x.
7. The kernel shape is a design parameter for which the original LOESS model uses a tricubic kernel :

$$h_i(x) = h(x - x_i) = \exp(-k(x - x_i)^2),$$

where k is a smoothing parameter.

8. For brevity, we will drop the argument x for $h_i(x)$, and define $n = \Sigma_i h_i$. We can then write the estimated means and covariances as :

$$\mu_x = \frac{\Sigma_i h_i x_i}{n}, \sigma_x^2 = \frac{\Sigma_i h_i (x_i - \mu_x)^2}{n}, \sigma_{xy} = \frac{\Sigma_i h_i (x_i - \mu_x)(y_i - \mu_y)}{n}$$

$$\mu_y = \frac{\Sigma_i h_i y_i}{n}, \sigma_y^2 = \frac{\Sigma_i h_i (y_i - \mu_y)^2}{n}, \sigma_{y/x}^2 = \sigma_y^2 - \frac{\sigma_{xy}^2}{\sigma_x^2}$$

9. We use the data covariances to express the conditional expectations and their estimated variances :

$$\hat{y} = \mu_y + \frac{\sigma_{xy}}{\sigma_x^2}(x - \mu_x), \frac{\sigma_{y/x}^2}{n^2}\left(\sum_i h_i^2 + \frac{(x - \mu_x)^2}{\sigma_x^2}\sum_i h_i^2 \frac{(x_i - \mu_x)^2}{\sigma_x^2}\right)$$

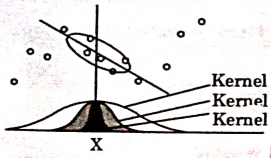


Fig. 3.20.2.

Que 3.21. Explain Radial Basis Function (RBF).

Answer

1. A Radial Basis Function (RBF) is a function that assigns a real value to each input from its domain (it is a real-value function), and the value produced by the RBF is always an absolute value *i.e.*, it is a measure of distance and cannot be negative.

2. Euclidean distance (the straight-line distance) between two points in Euclidean space is used.
3. Radial basis functions are used to approximate functions, such as neural networks acts as function approximators.
4. The following sum represents a radial basis function network :

$$y(x) = \sum_{i=1}^{N} w_i \, \phi(\| x - x_i \|) ,$$

5. The radial basis functions act as activation functions.
6. The approximant $y(x)$ is differentiable with respect to the weights which are learned using iterative update methods common among neural networks.

Que 3.22. Explain the architecture of a radial basis function network.

Answer

1. Radial Basis Function (RBF) networks have three layers : an input layer, a hidden layer with a non-linear RBF activation function and a linear output layer.
2. The input can be modeled as a vector of real numbers $x \in R^n$.
3. The output of the network is then a scalar function of the input vector, $\phi : R^n \rightarrow R$, and is given by

$$\phi(x) = \sum_{i=1}^{N} a_i \, \rho(\| x - c_i \|)$$

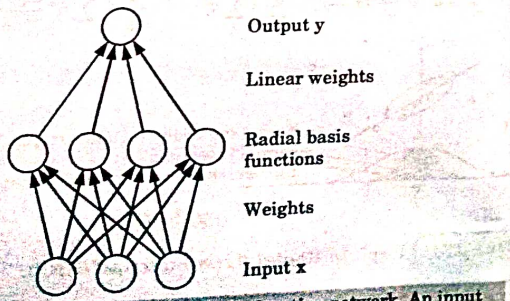


Fig. 3.22.1. Architecture of a radial basis function network. An input vector x is used as input to all radial basis functions, each with different parameters. The output of the network is a linear combination of the outputs from radial basis functions.

where n is the number of neurons in the hidden layer, c_i is the center vector for neuron i and a_i is the weight of neuron i in the linear output neuron.

4. Functions that depend only on the distance from a center vector are radially symmetric about that vector.
5. In the basic form all inputs are connected to each hidden neuron.
6. The radial basis function is taken to be Gaussian

$$\rho(\| x - c_i \|) = \exp\left[-\beta \| x - c_i \|^2\right]$$

7. The Gaussian basis functions are local to the center vector in the sense that

$$\lim_{\|x\| \rightarrow \infty} \rho(\| x - c_i \|) = 0$$

i.e., changing parameters of one neuron has only a small effect for input values that are far away from the center of that neuron.

8. Given certain mild conditions on the shape of the activation function, RBF networks are universal approximators on a compact subset of R^n.
9. This means that an RBF network with enough hidden neurons can approximate any continuous function on a closed, bounded set with arbitrary precision.
10. The parameters a_i, c_i, ρ, and β are determined in a manner that optimizes the fit between ϕ and the data.

PART-5

Case-based Learning.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.23. Write short note on case-based learning algorithm.

Answer

1. Case-Based Learning (CBL) algorithms contain an input as a sequence of training cases and an output concept description, which can be used to generate predictions of goal feature values for subsequently presented cases.

2. The primary component of the concept description is case-base, but almost all CBL algorithms maintain additional related information for the purpose of generating accurate predictions (for example, settings for feature weights).
3. Current CBL algorithms assume that cases are described using a feature-value representation, where features are either predictor or goal features.
4. CBL algorithms are distinguished by their processing behaviour.

Disadvantages of case-based learning algorithm :

1. They are computationally expensive because they save and compute similarities to all training cases.
2. They are intolerant of noise and irrelevant features.
3. They are sensitive to the choice of the algorithm's similarity function.
4. There is no simple way they can process symbolic valued feature values.

Que 3.24. What are the functions of case-based learning algorithm ?

Answer

Functions of case-based learning algorithm are :

1. **Pre-processor :** This prepares the input for processing (for example, normalizing the range of numeric-valued features to ensure that they are treated with equal importance by the similarity function, formatting the raw input into a set of cases).
2. **Similarity :**
   a. This function assesses the similarities of a given case with the previously stored cases in the concept description.
   b. Assessment may involve explicit encoding and/or dynamic computation.
   c. CBL similarity functions find a compromise along the continuum between these extremes.
3. **Prediction :** This function inputs the similarity assessments and generates a prediction for the value of the given case's goal feature (*i.e.*, a classification when it is symbolic-valued).
4. **Memory updating :** This updates the stored case-base, such as by modifying or abstracting previously stored cases, forgetting cases presumed to be noisy, or updating a feature's relevance weight setting.

Que 3.25. Describe case-based learning cycle with different schemes of CBL.

Answer

Case-based learning algorithm processing stages are :

1. **Case retrieval :** After the problem situation has been assessed, the best matching case is searched in the case-base and an approximate solution is retrieved.
2. **Case adaptation :** The retrieved solution is adapted to fit better in the new problem.

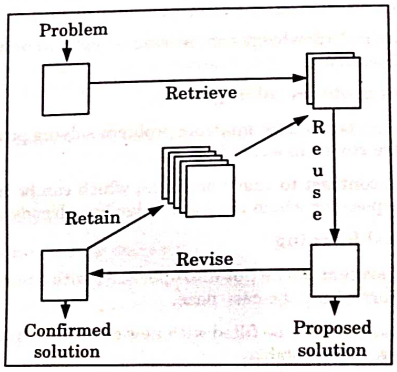


Fig. 3.25.1. The CBL cycle.

3. **Solution evaluation :**
   a. The adapted solution can be evaluated either before the solution is applied to the problem or after the solution has been applied.
   b. In any case, if the accomplished result is not satisfactory, the retrieved solution must be adapted again or more cases should be retrieved.
4. **Case-base updating :** If the solution was verified as correct, the new case may be added to the case base.

Different scheme of the CBL working cycle are :

1. Retrieve the most similar case.
2. Reuse the case to attempt to solve the current problem.
3. Revise the proposed solution if necessary.

4. Retain the new solution as a part of a new case.

Que 3.26. What are the benefits of CBL as a lazy problem solving method ?

Answer

The benefits of CBL as a lazy Problem solving method are :

1. **Ease of knowledge elicitation :**
   a. Lazy methods can utilise easily available case or problem instances instead of rules that are difficult to extract.
   b. So, classical knowledge engineering is replaced by case acquisition and structuring.
2. **Absence of problem-solving bias :**
   a. Cases can be used for multiple problem-solving purposes, because they are stored in a raw form.
   b. This in contrast to eager methods, which can be used merely for the purpose for which the knowledge has already been compiled.
3. **Incremental learning :**
   a. A CBL system can be put into operation with a minimal set solved cases furnishing the case base.
   b. The case base will be filled with new cases increasing the system's problem-solving ability.
   c. Besides augmentation of the case base, new indexes and clusters categories can be created and the existing ones can be changed.
   d. This in contrast requires a special training period whenever informatics extraction (knowledge generalisation) is performed.
   e. Hence, dynamic on-line adaptation a non-rigid environment is possible.
4. **Suitability for complex and not-fully formalised solution spaces :**
   a. CBL systems can applied to an incomplete model of problem domain, implementation involves both to identity relevant case features and to furnish, possibly a partial case base, with proper cases.
   b. Lazy approaches are appropriate for complex solution spaces than eager approaches, which replace the presented data with abstractions obtained by generalisation.

5. **Suitability for sequential problem solving :**
   a. Sequential tasks, like these encountered reinforcement learning problems, benefit from the storage of history in the form of sequence of states or procedures.
   b. Such a storage is facilitated by lazy approaches.
6. **Ease of explanation :**
   a. The results of a CBL system can be justified based upon the similarity of the current problem to the retrieved case.
   b. CBL are easily traceable to precedent cases, it is also easier to analyse failures of the system.
7. **Ease of maintenance :** This is particularly due to the fact that CBL systems can adapt to many changes in the problem domain and the relevant environment, merely by acquiring.

Que 3.27. What are the limitations of CBL ?

Answer

Limitations of CBL are :

1. **Handling large case bases :**
   a. High memory/storage requirements and time-consuming retrieval accompany CBL systems utilising large case bases.
   b. Although the order of both is linear with the number of cases, these problems usually lead to increased construction costs and reduced system performance.
   c. These problems are less significant as the hardware components become faster and cheaper.
2. **Dynamic problem domains :**
   a. CBL systems may have difficulties in handling dynamic problem domains, where they may be unable to follow a shift in the way problems are solved, since they are strongly biased towards what has already worked.
   b. This may result in an outdated case base.
3. **Handling noisy data :**
   a. Parts of the problem situation may be irrelevant to the problem itself.

b. Unsuccessful assessment of such noise present in a problem situation currently imposed on a CBL system may result in the same problem being unnecessarily stored numerous times in the case base because of the difference due to the noise.

c. In turn this implies inefficient storage and retrieval of cases.

4. **Fully automatic operation :**

a. In a CBL system, the problem domain is not fully covered.

b. Hence, some problem situations can occur for which the system has no solution.

c. In such situations, CBL systems expect input from the user.

Que 3.28. What are the applications of CBL ?

Answer

Applications of CBL :

1. **Interpretation :** It is a process of evaluating situations / problems in some context (For example, HYPO for interpretation of patent laws KICS for interpretation of building regulations, LISSA for interpretation of non-destructive test measurements).
2. **Classification :** It is a process of explaining a number of encountered symptoms (For example, CASEY for classification of auditory impairments, CASCADE for classification of software failures, PAKAR for causal classification of building defects, ISFER for classification of facial expressions into user defined interpretation categories.
3. **Design :** It is a process of satisfying a number of posed constraints (For example, JULIA for meal planning, CLAVIER for design of optimal layouts of composite airplane parts, EADOCS for aircraft panels design).
4. **Planning :** It is a process of arranging a sequence of actions in time (For example, BOLERO for building diagnostic plans for medical patients, TOTLEC for manufacturing planning).
5. **Advising :** It is a process of resolving diagnosed problems (For example, DECIDER for advising students, HOMER).

Que 3.29. What are major paradigms of machine learning ?

Answer

Major paradigms of machine learning are :

1. **Rote Learning :**

a. There is one-to-one mapping from inputs to stored representation.

b. Learning by memorization.

c. There is Association-based storage and retrieval.

2. **Induction :** Machine learning use specific examples to reach general conclusions.
3. **Clustering :** Clustering is a task of grouping a set of objects in such a way that objects in the same group are similar to each other than to those in other group.
4. **Analogy :** Determine correspondence between two different representations.
5. **Discovery :** Unsupervised *i.e.*, specific goal not given.
6. **Genetic algorithms :**

a. Genetic algorithms are stochastic search algorithms which act on a population of possible solutions.

b. They are probabilistic search methods means that the states which they explore are not determined solely by the properties of the problems.

7. **Reinforcement :**

a. In reinforcement only feedback (positive or negative reward) given at end of a sequence of steps.

b. Requires assigning reward to steps by solving the credit assignment problem which steps should receive credit or blame for a final result.

Que 3.30. Briefly explain the inductive learning problem.

Answer

Inductive learning problem are :

1. **Supervised versus unsupervised learning :**

a. We want to learn an unknown function $f(x) = y$, where x is an input example and y is the desired output.

b. Supervised learning implies we are given a set of (x, y) pairs by a teacher.

c. Unsupervised learning means we are only given the xs.

d. In either case, the goal is to estimate f.

2. **Concept learning :**

a. Given a set of examples of some concept/class/category, determine if a given example is an instance of the concept or not.

b. If it is an instance, we call it a positive example.

c. If it is not, it is called a negative example.

3. **Supervised concept learning by induction :**
   a. Given a training set of positive and negative examples of a concept, construct a description that will accurately classify whether future examples are positive or negative.
   b. That is, learn some good estimate of function f given a training set $\{(x1, y1), (x2, y2), ..., (xn, yn)\}$ where each y_i is either + (positive) or – (negative).

4 UNIT

Artificial Neural Network and Deep Learning

CONTENTS

PART-1

Artifical Neural Network, Perceptron's Multilayer Perceptron, Gradient Descent and the Delta Rule.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.1. Describe Artificial Neural Network (ANN) with different layers.

Answer

Artificial Neural Network : Refer Q. 1.13, Page 1–14L, Unit-1.

A neural network contains the following three layers :

a. **Input layer :** The activity of the input units represents the raw information that can feed into the network.

b. **Hidden layer :**

i. Hidden layer is used to determine the activity of each hidden unit.

ii. The activities of the input units and the weights depend on the connections between the input and the hidden units.

iii. There may be one or more hidden layers.

c. **Output layer :** The behaviour of the output units depends on the activity of the hidden units and the weights between the hidden and output units.

Que 4.2. What are the advantages and disadvantage of Artificial Neural Network ?

Answer

Advantages of Artificial Neural Networks (ANN) :

1. Problems in ANN are represented by attribute-value pairs.
2. ANNs are used for problems having the target function, output may be discrete-valued, real-valued, or a vector of several real or discrete-valued attributes.
3. ANNs learning methods are quite robust to noise in the training data. The training examples may contain errors, which do not affect the final output.

4. It is used where the fast evaluation of the learned target function required.
5. ANNs can bear long training times depending on factors such as the number of weights in the network, the number of training examples considered, and the settings of various learning algorithm parameters.

Disadvantages of Artificial Neural Networks (ANN) :

1. **Hardware dependence :**
   a. Artificial neural networks require processors with parallel processing power, by their structure.
   b. For this reason, the realization of the equipment is dependent.
2. **Unexplained functioning of the network :**
   a. This is the most important problem of ANN.
   b. When ANN gives a probing solution, it does not give a clue as to why and how.
   c. This reduces trust in the network.
3. **Assurance of proper network structure :**
   a. There is no specific rule for determining the structure of artificial neural networks.
   b. The appropriate network structure is achieved through experience and trial and error.
4. **The difficulty of showing the problem to the network :**
   a. ANNs can work with numerical information.
   b. Problems have to be translated into numerical values before being introduced to ANN.
   c. The display mechanism to be determined will directly influence the performance of the network.
   d. This is dependent on the user's ability.
5. **The duration of the network is unknown :**
   a. The network is reduced to a certain value of the error on the sample means that the training has been completed.
   b. This value does not give us optimum results.

Que 4.3. What are the characteristics of Artificial Neural Network ?

Answer

Characteristics of Artificial Neural Network are :

1. It is neurally implemented mathematical model.
2. It contains large number of interconnected processing elements called neurons to do all the operations.

3. Information stored in the neurons is basically the weighted linkage of neurons.
4. The input signals arrive at the processing elements through connections and connecting weights.
5. It has the ability to learn, recall and generalize from the given data by suitable assignment and adjustment of weights.
6. The collective behaviour of the neurons describes its computational power, and no single neuron carries specific information.

Que 4.4. Explain the application areas of artificial neural network.

Answer

Application areas of artificial neural network are :

1. **Speech recognition :**
   a. Speech occupies a prominent role in human-human interaction.
   b. Therefore, it is natural for people to expect speech interfaces with computers.
   c. In the present era, for communication with machines, humans still need sophisticated languages which are difficult to learn and use.
   d. To ease this communication barrier, a simple solution could be communication in a spoken language that is possible for the machine to understand.
   e. Hence, ANN is playing a major role in speech recognition.
2. **Character recognition :**
   a. It is a problem which falls under the general area of Pattern Recognition.
   b. Many neural networks have been developed for automatic recognition of handwritten characters, either letters or digits.
3. **Signature verification application :**
   a. Signatures are useful ways to authorize and authenticate a person in legal transactions.
   b. Signature verification technique is a non-vision based technique.
   c. For this application, the first approach is to extract the feature or rather the geometrical feature set representing the signature.
   d. With these feature sets, we have to train the neural networks using an efficient neural network algorithm.
   e. This trained neural network will classify the signature as being genuine or forged under the verification stage.
4. **Human face recognition :**
   a. It is one of the biometric methods to identify the given face.

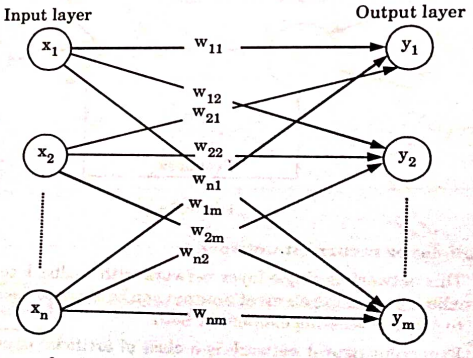
   b. It is a typical task because of the characterization of "non-face" images.
   c. However, if a neural network is well trained, then it can be divided into two classes namely images having faces and images that do not have faces.

Que 4.5. Explain different types of neuron connection with architecture.

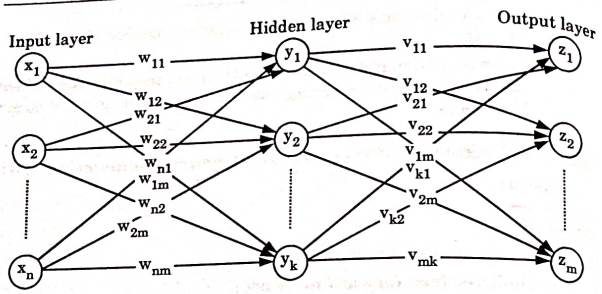
Answer

Different types of neuron connection are :

1. **Single-layer feed forward network :**
   a. In this type of network, we have only two layers *i.e.*, input layer and output layer but input layer does not count because no computation is performed in this layer.
   b. Output layer is formed when different weights are applied on input nodes and the cumulative effect per node is taken.
   c. After this the neurons collectively give the output layer to compute the output signals.



2. **Multilayer feed forward network :**
   a. This layer has hidden layer which is internal to the network and has no direct contact with the external layer.
   b. Existence of one or more hidden layers enables the network to be computationally stronger.
   c. There are no feedback connections in which outputs of the model are fed back into itself.



3. Single node with its own feedback :

a. When outputs can be directed back as inputs to the same layer or preceding layer nodes, then it results in feedback networks.

b. Recurrent networks are feedback networks with closed loop. Fig. 4.5.1 shows a single recurrent network having single neuron with feedback to itself.

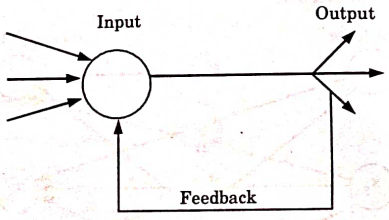


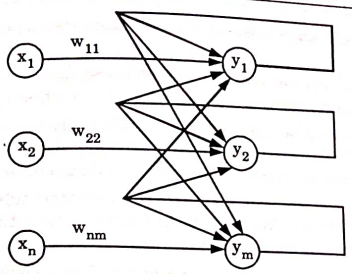
Fig. 4.5.1.

4. Single-layer recurrent network :

a. This network is single layer network with feedback connection in which processing element's output can be directed back to itself or to other processing element or both.

b. Recurrent neural network is a class of artificial neural network where connections between nodes form a directed graph along a sequence.

c. This allows it to exhibit dynamic temporal behaviour for a time sequence. Unlike feed forward neural networks, RNNs can use their internal state (memory) to process sequences of inputs.

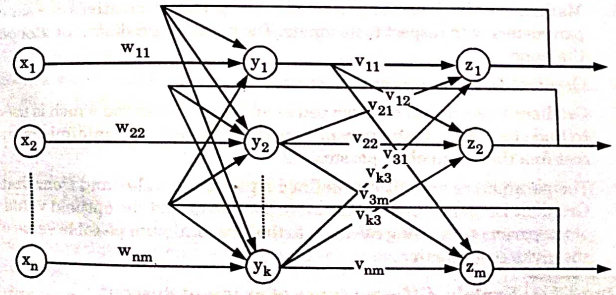


5. Multilayer recurrent network :

a. In this type of network, processing element output can be directed to the processing element in the same layer and in the preceding layer forming a multilayer recurrent network.

b. They perform the same task for every element of a sequence, with the output being depended on the previous computations. Inputs are not needed at each time step.

c. The main feature of a multilayer recurrent neural network is its hidden state, which captures information about a sequence.



Que 4.6. Discuss the benefits of artificial neural network.

Answer

1. Artificial neural networks are flexible and adaptive.
2. Artificial neural networks are used in sequence and pattern recognition systems, data processing, robotics, modeling, etc.
3. ANN acquires knowledge from their surroundings by adapting to internal and external parameters and they solve complex problems which are difficult to manage.

4. It generalizes knowledge to produce adequate responses to unknown situations.
5. Artificial neural networks are flexible and have the ability to learn, generalize and adapts to situations based on its findings.
6. This function allows the network to efficiently acquire knowledge by learning. This is a distinct advantage over a traditionally linear network that is inadequate when it comes to modelling non-linear data.
7. An artificial neuron network is capable of greater fault tolerance than a traditional network. Without the loss of stored data, the network is able to regenerate a fault in any of its components.
8. An artificial neuron network is based on adaptive learning.

Que 4.7. **Write short note on gradient descent.**

Answer

1. Gradient descent is an optimization algorithm used to minimize some function by iteratively moving in the direction of steepest descent as defined by the negative of the gradient.
2. A gradient is the slope of a function, the degree of change of a parameter with the amount of change in another parameter.
3. Mathematically, it can be described as the partial derivatives of a set of parameters with respect to its inputs. The more the gradient, the steeper the slope.
4. Gradient Descent is a convex function.
5. Gradient Descent can be described as an iterative method which is used to find the values of the parameters of a function that minimizes the cost function as much as possible.
6. The parameters are initially defined a particular value and from that, Gradient Descent run in an iterative fashion to find the optimal values of the parameters, using calculus, to find the minimum possible value of the given cost function.

Que 4.8. **Explain different types of gradient descent.**

Answer

Different types of gradient descent are :

1. **Batch gradient descent :**
   a. This is a type of gradient descent which processes all the training examples for each iteration of gradient descent.
   b. When the number of training examples is large, then batch gradient descent is computationally very expensive. So, it is not preferred.
   c. Instead, we prefer to use stochastic gradient descent or mini-batch gradient descent.

2. **Stochastic gradient descent :**
   a. This is a type of gradient descent which processes single training example per iteration.
   b. Hence, the parameters are being updated even after one iteration in which only a single example has been processed.
   c. Hence, this is faster than batch gradient descent. When the number of training examples is large, even then it processes only one example which can be additional overhead for the system as the number of iterations will be large.
3. **Mini-batch gradient descent :**
   a. This is a mixture of both stochastic and batch gradient descent.
   b. The training set is divided into multiple groups called batches.
   c. Each batch has a number of training samples in it.
   d. At a time, a single batch is passed through the network which computes the loss of every sample in the batch and uses their average to update the parameters of the neural network.

Que 4.9. **What are the advantages and disadvantages of batch gradient descent ?**

Answer

Advantages of batch gradient descent :

1. Less oscillations and noisy steps taken towards the global minima of the loss function due to updating the parameters by computing the average of all the training samples rather than the value of a single sample.
2. It can benefit from the vectorization which increases the speed of processing all training samples together.
3. It produces a more stable gradient descent convergence and stable error gradient than stochastic gradient descent.
4. It is computationally efficient as all computer resources are not being used to process a single sample rather are being used for all training samples.

Disadvantages of batch gradient descent :

1. Sometimes a stable error gradient can lead to a local minima and unlike stochastic gradient descent no noisy steps are there to help to get out of the local minima.
2. The entire training set can be too large to process in the memory due to which additional memory might be needed.
3. Depending on computer resources it can take too long for processing all the training samples as a batch.

Que 4.10. **What are the advantages and disadvantages of stochastic gradient descent ?**

Answer

Advantages of stochastic gradient descent :

1. It is easier to fit into memory due to a single training sample being processed by the network.
2. It is computationally fast as only one sample is processed at a time.
3. For larger datasets it can converge faster as it causes updates to the parameters more frequently.
4. Due to frequent updates the steps taken towards the minima of the loss function have oscillations which can help getting out of local minimums of the loss function (in case the computed position turns out to be the local minimum).

Disadvantages of stochastic gradient descent :

1. Due to frequent updates the steps taken towards the minima are very noisy. This can often lead the gradient descent into other directions.
2. Also, due to noisy steps it may take longer to achieve convergence to the minima of the loss function.
3. Frequent updates are computationally expensive due to using all resources for processing one training sample at a time.
4. It loses the advantage of vectorized operations as it deals with only a single example at a time.

Que 4.11. Explain delta rule. Explain generalized delta learning rule (error backpropagation learning rule).

Answer

Delta rule :

1. The delta rule is specialized version of backpropagation's learning rule that uses single layer neural networks.
2. It calculates the error between calculated output and sample output data, and uses this to create a modification to the weights, thus implementing a form of gradient descent.

Generalized delta learning rule (Error backpropagation learning) :

In generalized delta learning rule (error backpropagation learning). We are given the training set :

$$(x^1, y^1), \ldots, (x^k, y^k)$$

where $x^k = [x^k{}_1, \ldots x_n{}^k]$ and $y^k \in R, k = 1, \ldots, K$.

Step 1 : $\eta > 0, E_{max} > 0$ are chosen.

Step 2 : Weights w are initialized at small random values, $k = 1$, and the running error E is set to 0.

Step 3 : Input x^k is presented, $x := x^k, y := y^k$, and output O is computed as :

$$O = \frac{1}{1 + \exp(-W^T O)}$$

where O_t is the output vector of the hidden layer :

$$O_l = \frac{1}{1 + \exp(-W_l^T x)}$$

Step 4 : Weights of the output unit are updated

$$W := W + \eta\delta o$$

where $\delta = (y - O)O(1 - O)$

Step 5 : Weights of the hidden units are updated

$$w_t = w_t + \eta\delta W_t O_t(1 - O_t)x, l = 1, \ldots, L$$

Step 6 : Cumulative cycle error is computed by adding the present error to E

$$E := E + 1/2(y - O)^2$$

Step 7 : If $k < K$ then $k := k + 1$ and we continue the training by going back to step 2, otherwise we go to step 8.

Step 8 : The training cycle is completed. For $E < E_{max}$ terminate the training session. If $E > E_{max}$ then $E := 0, k := 1$ and we initiate a new training cycle by going back to step 3.

PART-2

Multilayer Network, Derivation of Back Propagation Algorithm, Generalization.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.12. Write short note on backpropagation algorithm.

Answer

1. Backpropagation is an algorithm used in the training of feedforward neural networks for supervised learning.
2. Backpropagation efficiently computes the gradient of the loss function with respect to the weights of the network for a single input-output example.
3. This makes it feasible to use gradient methods for training multi-layer networks, updating weights to minimize loss, we use gradient descent or variants such as stochastic gradient descent.

4. The backpropagation algorithm works by computing the gradient of the loss function with respect to each weight by the chain rule, iterating backwards one layer at a time from the last layer to avoid redundant calculations of intermediate terms in the chain rule; this is an example of dynamic programming.
5. The term backpropagation refers only to the algorithm for computing the gradient, but it is often used loosely to refer to the entire learning algorithm, also including how the gradient is used, such as by stochastic gradient descent.
6. Backpropagation generalizes the gradient computation in the delta rule, which is the single-layer version of backpropagation, and is in turn generalized by automatic differentiation, where backpropagation is a special case of reverse accumulation (reverse mode).

Que 4.13. Explain perceptron with single flow graph.

Answer

1. The perceptron is the simplest form of a neural network used for classification of patterns said to be linearly separable.
2. It consists of a single neuron with adjustable synaptic weights and bias.
3. The perceptron build around a single neuron is limited for performing pattern classification with only two classes.
4. By expanding the output layer of perceptron to include more than one neuron, more than two classes can be classified.
5. Suppose, a perceptron have synaptic weights denoted by $w_1, w_2, w_3, \ldots\ldots w_m$.
6. The input applied to the perceptron are denoted by $x_1, x_2, \ldots\ldots x_m$.
7. The externally applied bias is denoted by b.

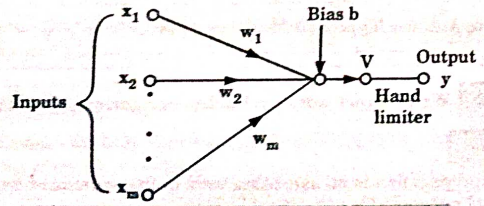


Fig. 4.13.1. Signal flow graph of the perceptron.

8. From the model, we find that the hard limiter input or induced local field of the neuron as

$$V = \sum_{i=1}^{m} w_i x_i + b$$

9. The goal of the perceptron is to correctly classify the set of externally applied input $x_1, x_2, \ldots\ldots x_m$ into one of two classes G_1 and G_2.
10. The decision rule for classification is that if output y is +1 then assign the point represented by input $x_1, x_2, \ldots\ldots x_m$ to class G_1 else y is –1 then assign to class G_2.
11. In Fig. 4.13.2, if a point (x_1, x_2) lies below the boundary lines is assigned to class G_2 and above the line is assigned to class G_1. Decision boundary is calculated as :

$$w_1x_1 + w_2x_2 + b = 0$$

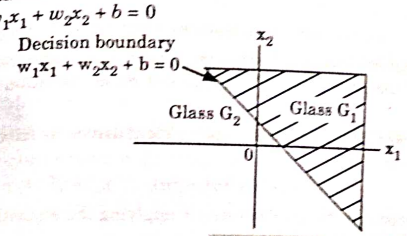


Fig. 4.13.2.

12. There are two decision regions separated by a hyperplane defined as :

$$\sum_{i=1}^{m} w_i x_i + b = 0$$

The synaptic weights $w_1, w_2, \ldots\ldots w_m$ of the perceptron can be adapted on an iteration by iteration basis.

13. For the adaption, an error-correction rule known as perceptron convergence algorithm is used.
14. For a perceptron to function properly, the two classes G_1 and G_2 must be linearly separable.
15. Linearly separable means, the pattern or set of inputs to be classified must be separated by a straight line.
16. Generalizing, a set of points in n-dimensional space are linearly separable if there is a hyperplane of $(n-1)$ dimensions that separates the sets.

(a) A pair of linearly separable patterns

(b) A pair of non-linearly separable patterns

Fig. 4.13.3.

Que 4.14. State and prove perceptron convergence theorem.

Answer

Statement : The Perceptron convergence theorem states that for any data set which is linearly separable the Perceptron learning rule is guaranteed to find a solution in a finite number of steps.

Proof :

1. To derive the error-correction learning algorithm for the perceptron.
2. The perceptron convergence theorem used the synaptic weights $w_1, w_2, \ldots w_m$ of the perceptron can be adapted on an iteration by iteration basis.
3. The bias $b(n)$ is treated as a synaptic weight driven by fixed input equal to + 1.

$$x(n) = [+1, x_1(n), x_2(n), \ldots x_m(n)]^T$$

Where n denotes the iteration step in applying the algorithm.

4. Correspondingly, we define the weight vector as

$$w(n) = [b(n), w_1(n), w_2(n) \ldots\ldots, w_m(n)]^T$$

Accordingly, the linear combiner output is written in the compact form :

$$v(n) = \sum_{i=0}^{n} w_i(n)\, x_i(n) = w^T(n)\, x(n)$$

The algorithm for adapting the weight vector is stated as :

1. If the nth member of input set $x(n)$, is correctly classified into linearly separable classes, by the weight vector $w(n)$ (that is output is correct) then no adjustment of weights are done.

$$w(n+1) = w(n)$$

if $w^T x(n) > 0$ and $x(n)$ belongs to class G_1.

$$w(n+1) = w(n)$$

if $w^T x(n) \leq 0$ and $x(n)$ belongs to class G_2.

2. Otherwise, the weight vector of the perceptron is updated in accordance with the rule :

$$w(n+1) = w(n) - \eta(n)\, x(n)$$

if $w^T(n)\, x(n) > 0$ and $x(n)$ belongs to class G_2.

$$w(n+1) = w(n) - \eta(n)\, x(n)$$

if $w^T(n)\, x(n) \leq 0$ and $x(n)$ belongs to class G_1.

where $\eta(n)$ is the learning-rate parameter for controlling the adjustment applied to the weight vector at iteration n.

Also small α leads to slow learning and large α leads to fast learning. For a constant α, the learning algorithm is termed as fixed increment algorithm.

Que 4.15. Explain multilayer perceptron with its architecture and characteristics.

Answer

Multilayer perceptron :

1. The perceptrons which are arranged in layers are called multilayer perceptron. This model has three layers : an input layer, output layer and hidden layer.
2. For the perceptrons in the input layer, the linear transfer function used and for the perceptron in the hidden layer and output layer, the sigmoidal or squashed-S function is used.
3. The input signal propagates through the network in a forward direction.
4. On a layer by layer basis, in the multilayer perceptron bias $b(n)$ is treated as a synaptic weight driven by fixed input equal to +1.

$$x(n) = [+1, x_1(n), x_2(n), \ldots\ldots\ldots x_m(n)]^T$$

where n denotes the iteration step in applying the algorithm.

Correspondingly, we define the weight vector as :

$$w(n) = [b(n), w_1(n), w_2(n)\ldots\ldots\ldots, w_m(n)]^T$$

5. Accordingly, the linear combiner output is written in the compact form :

$$V(n) = \sum_{i=0}^{m} w_i(n) x_i(n) = w^T(n) \times x(n)$$

The algorithm for adapting the weight vector is stated as :

1. If the nth number of input set $x(n)$, is correctly classified into linearly separable classes, by the weight vector $w(n)$ (that is output is correct) then no adjustment of weights are done.

$$w(n+1) = w(n)$$

if $w^T x(n) > 0$ and $x(n)$ belongs to class G_1.

$$w(n+1) = w(n)$$

if $w^T x(n) \leq 0$ and $x(n)$ belongs to class G_2.

2. Otherwise, the weight vector of the perceptron is updated in accordance with the rule.

Architecture of multilayer perceptron :

1. Fig. 4.15.1 shows architectural graph of multilayer perceptron with two hidden layer and an output layer.
2. Signal flow through the network progresses in a forward direction, from the left to right and on a layer-by-layer basis.
3. Two kinds of signals are identified in this network :
   a. **Functional signals :** Functional signal is an input signal and propagates forward and emerges at the output end of the network as an output signal.

b. **Error signals:** Error signal originates at an output neuron and propagates backward through the network.

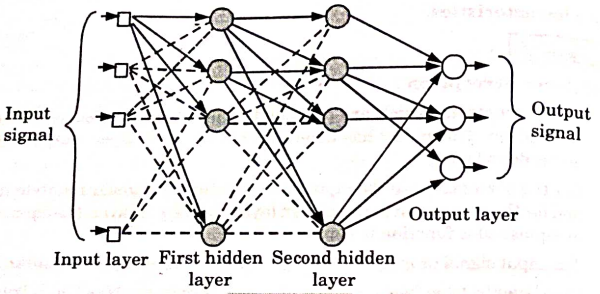


Fig. 4.15.1.

4. Multilayer perceptrons have been applied successfully to solve some difficult and diverse problems by training them in a supervised manner with highly popular algorithm known as the error backpropagation algorithm.

Characteristics of multilayer perceptron :

1. In this model, each neuron in the network includes a non-linear activation function (non-linearity is smooth). Most commonly used non-linear function is defined by :

$$y_j = \frac{1}{1+\exp(-v_j)}$$

where v_j is the induced local field (*i.e.*, the sum of all weights and bias) and y is the output of neuron j.

2. The network contains hidden neurons that are not a part of input or output of the network. Hidden layer of neurons enabled network to learn complex tasks.
3. The network exhibits a high degree of connectivity.

Que 4.16. How tuning parameters effect the backpropagation neural network ?

Answer

Effect of tuning parameters of the backpropagation neural network:

1. Momentum factor :

a. The momentum factor has a significant role in deciding the values of learning rate that will produce rapid learning.

b. It determines the size of change in weights or biases.

c. If momentum factor is zero, the smoothening is minimum and the entire weight adjustment comes from the newly calculated change.

d. If momentum factor is one, new adjustment is ignored and previous one is repeated.

e. Between 0 and 1 is a region where the weight adjustment is smoothened by an amount proportional to the momentum factor.

f. The momentum factor effectively increases the speed of learning without leading to oscillations and filters out high frequency variations of the error surface in the weight space.

2. Learning coefficient :

a. A formula to select learning coefficient is :

$$h = \frac{1.5}{(N_1^2 + N_2^2 + ... + N_m^2)}$$

Where N_1 is the number of patterns of type 1 and m is the number of different pattern types.

b. The small value of learning coefficient less than 0.2 produces slower but stable training.

c. The largest value of learning coefficient *i.e.*, greater than 0.5, the weights are changed drastically but this may cause optimum combination of weights to be overshot resulting in oscillations about the optimum.

d. The optimum value of learning rate is 0.6 which produce fast learning without leading to oscillations.

3. Sigmoidal gain :

a. If sigmoidal function is selected, the input-output relationship of the neuron can be set as

$$O = \frac{1}{(1+e^{-\lambda(1+\theta)})} \quad ...(4.16.1)$$

where λ is a scaling factor known as sigmoidal gain.

b. As the scaling factor increases, the input-output characteristic of the analog neuron approaches that of the two state neuron or the activation function approaches the (Satisifiability) function.

c. It also affects the backpropagation. To get graded output, as the sigmoidal gain factor is increased, learning rate and momentum factor have to be decreased in order to prevent oscillations.

4. Threshold value :

a. θ in eq. (4.16.1) is called as threshold value or the bias or the noise factor.

b. A neuron fires or generates an output if the weighted sum of the input exceeds the threshold value.

c. One method is to simply assign a small value to it and not to change it during training.

d. The other method is to initially choose some random values and change them during training.

Que 4.17. Discuss selection of various parameters in Backpropagation Neural Network (BPN).

Answer

Selection of various parameters in BPN :

1. **Number of hidden nodes :**

a. The guiding criterion is to select the minimum nodes in the first and third layer, so that the memory demand for storing the weights can be kept minimum.

b. The number of separable regions in the input space M, is a function of the number of hidden nodes H in BPN and H = M – 1.

c. When the number of hidden nodes is equal to the number of training patterns, the learning could be fastest.

d. In such cases, BPN simply remembers training patterns losing all generalization capabilities.

e. Hence, as far as generalization is concerned, the number of hidden nodes should be small compared to the number of training patterns with help of Vapnik Chervonenkis dimension (VCdim) of probability theory.

f. We can estimate the selection of number of hidden nodes for a given number of training patterns as number of weights which is equal to $I_1 * I_2 + I_2 * I_3$, where I_1 and I_3 denote input and output nodes and I_2 denote hidden nodes.

g. Assume the training samples T to be greater than VCdim. Now if we accept the ratio 10 : 1

$$10 * T = \frac{I_2}{(I_1 + I_3)}$$

$$I_2 = \frac{10T}{(I_1 + I_3)}$$

Which yields the value for I_2.

2. **Momentum coefficient α :**

a. To reduce the training time we use the momentum factor because it enhances the training process.

b. The influences of momentum on weight change is

$$[\Delta W]^{n+1} = -\eta \frac{\partial E}{\partial W} + \alpha[\Delta W]^n$$

c. The momentum also overcomes the effect of local minima.

d. The use of momentum term will carry a weight change process through one or local minima and get it into global minima.

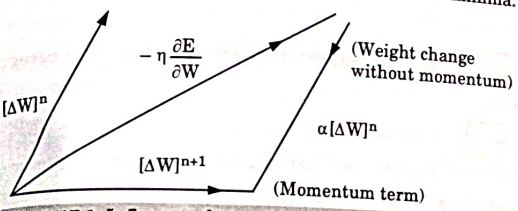


Fig. 4.17.1. Influence of momentum term on weight change.

3. **Sigmoidal gain λ :**

a. When the weights become large and force the neuron to operate in a region where sigmoidal function is very flat, a better method of coping with network paralysis is to adjust the sigmoidal gain.

b. By decreasing this scaling factor, we effectively spread out sigmoidal function on wide range so that training proceeds faster.

4. **Local minima :**

a. One of the most practical solutions involves the introduction of a shock which changes all weights by specific or random amounts.

b. If this fails, then the most practical solution is to rerandomize the weights and start the training all over.

PART-3

Unsupervised Learning, SOM Algorithm and its Variants.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.18. Write short note on unsupervised learning.

Answer

1. Unsupervised learning is the training of machine using information that is neither classified nor labeled and allowing the algorithm to act on that information without guidance.

2. Here the task of machine is to group unsorted information according to similarities, patterns and differences without any prior training of data.
3. Unlike supervised learning, no teacher is provided that means no training will be given to the machine.
4. Therefore machine is restricted to find the hidden structure in unlabeled data by our-self.

Que 4.19. Classify unsupervised learning into two categories of algorithm.

Answer

Classification of unsupervised learning algorithm into two categories :

1. **Clustering :** A clustering problem is where we want to discover the inherent groupings in the data, such as grouping customers by purchasing behavior.
2. **Association :** An association rule learning problem is where we want to discover rules that describe large portions of our data, such as people that buy X also tend to buy Y.

Que 4.20. What are the applications of unsupervised learning ?

Answer

Following are the application of unsupervised learning :

1. Unsupervised learning automatically split the dataset into groups base on their similarities.
2. Anomaly detection can discover unusual data points in our dataset. It is useful for finding fraudulent transactions.
3. Association mining identifies sets of items which often occur together in our dataset.
4. Latent variable models are widely used for data preprocessing. Like reducing the number of features in a dataset or decomposing the dataset into multiple components.

Que 4.21. What is Self-Organizing Map (SOM) ?

Answer

1. Self-Organizing Map (SOM) provides a data visualization technique which helps to understand high dimensional data by reducing the dimensions of data to a map.
2. SOM also represents clustering concept by grouping similar data together.

3. A self-Organizing Map (SOM) or Self-Organizing Feature Map (SOFM) is a type of Artificial Neural Network (ANN) that is trained using unsupervised learning to produce a low-dimensional (typically two-dimensional), discretized representation of the input space of the training samples, called a map, and is therefore a method to do dimensionality reduction.
4. Self-organizing maps differ from other artificial neural networks as they apply competitive learning as opposed to error-correction learning (such as backpropagation with gradient descent), and in the sense that they use a neighborhood function to preserve the topological properties of the input space.

Que 4.22. Write the steps used in SOM algorithm.

Answer

Following are the steps used in SOM algorithm :

1. Each node's weights are initialized.
2. A vector is chosen at random from the set of training data.
3. Every node is examined to calculate which one's weights are most like the input vector. The winning node is commonly known as the Best Matching Unit (BMU).
4. Then the neighbourhood of the BMU is calculated. The amount of neighbors decreases over time.
5. The winning weight is rewarded with becoming more like the sample vector. The neighbours also become more like the sample vector. The closer a node is to the BMU, the more its weights get altered and the farther away the neighbor is from the BMU, the less it learns.
6. Repeat step 2 for N iterations.

Que 4.23. What are the basic processes used in SOM ? Also explain stages of SOM algorithm.

Answer

Basics processes used in SOM algorithm are :

1. **Initialization :** All the connection weights are initialized with small random values.
2. **Competition :** For each input pattern, the neurons compute their respective values of a discriminant function which provides the basis for competition. The particular neuron with the smallest value of the discriminant function is declared the winner.

3. **Cooperation :** The winning neuron determines the spatial location of a topological neighbourhood of excited neurons, thereby providing the basis for cooperation among neighbouring neurons.
4. **Adaptation :** The excited neurons decrease their individual values of the discriminant function in relation to the input pattern through suitable adjustment of the associated connection weights, such that the response of the winning neuron to the subsequent application of a similar input pattern is enhanced.

Stages of SOM algorithm are :

1. **Initialization :** Choose random values for the initial weight vectors w_j.
2. **Sampling :** Draw a sample training input vector x from the input space.
3. **Matching :** Find the winning neuron $I(x)$ that has weight vector closest to the input vector, *i.e.*, the minimum value of $d_j(x) = \sum_{i=1}^{D} (x_i - w_{ji})^2$.
4. **Updating :** Apply the weight update equation

$$Dw_{ji} = h(t)\, T_{j, I(x)}(t)\, (x_i - w_{ji})$$

where $T_{j, I(x)}(t)$ is a Gaussian neighbourhood and $h(t)$ is the learning rate.

5. **Continuation :** Keep returning to step 2 until the feature map stops changing.

PART-4

Deep Learning, Introduction, Concept of Convolutional Neural Network, Types of Layers, (Convolutional Layers, Activation Function, Pooling, Fully Connected).

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.24. What do you understand by deep learning ?

Answer

1. Deep learning is the subfield of artificial intelligence that focuses on creating large neural network models that are capable of making accurate data-driven decisions.

2. Deep learning is used where the data is complex and has large datasets.
3. Facebook uses deep learning to analyze text in online conversations. Google and Microsoft all use deep learning for image search and machine translation.
4. All modern smart phones have deep learning systems running on them. For example, deep learning is the standard technology for speech recognition, and also for face detection on digital cameras.
5. In the healthcare sector, deep learning is used to process medical images (X-rays, CT, and MRI scans) and diagnose health conditions.
6. Deep learning is also at the core of self-driving cars, where it is used for localization and mapping, motion planning and steering, and environment perception, as well as tracking driver state.

Que 4.25. Describe different architecture of deep learning.

Answer

Different architecture of deep learning are :

1. **Deep Neural Network :** It is a neural network with a certain level of complexity (having multiple hidden layers in between input and output layers). They are capable of modeling and processing non-linear relationships.
2. **Deep Belief Network (DBN) :** It is a class of Deep Neural Network. It is multi-layer belief networks. Steps for performing DBN are :
   a. Learn a layer of features from visible units using Contrastive Divergence algorithm.
   b. Treat activations of previously trained features as visible units and then learn features of features.
   c. Finally, the whole DBN is trained when the learning for the final hidden layer is achieved.
3. **Recurrent (perform same task for every element of a sequence) Neural Network :** Allows for parallel and sequential computation. Similar to the human brain (large feedback network of connected neurons). They are able to remember important things about the input they received and hence enable them to be more precise.

Que 4.26. What are the advantages, disadvantages and limitation of deep learning ?

Answer

Advantages of deep learning :

1. Best in-class performance on problems.
2. Reduces need for feature engineering.
3. Eliminates unnecessary costs.
4. Identifies defects easily that are difficult to detect.

Disadvantages of deep learning :

1. Large amount of data required.
2. Computationally expensive to train.
3. No strong theoretical foundation.

Limitations of deep learning :

1. Learning through observations only.
2. The issue of biases.

Que 4.27. What are the various applications of deep learning ?

Answer

Following are the application of deep learning :

1. **Automatic text generation :** Corpus of text is learned and from this model new text is generated, word-by-word or character-by-character. Then this model is capable of learning how to spell, punctuate, form sentences, or it may even capture the style.
2. **Healthcare :** Helps in diagnosing various diseases and treating it.
3. **Automatic machine translation :** Certain words, sentences or phrases in one language is transformed into another language (Deep Learning is achieving top results in the areas of text, images).
4. **Image recognition :** Recognizes and identifies peoples and objects in images as well as to understand content and context. This area is already being used in Gaming, Retail, Tourism, etc.
5. **Predicting earthquakes :** Teaches a computer to perform viscoelastic computations which are used in predicting earthquakes.

Que 4.28. Define convolutional networks.

Answer

1. Convolutional networks also known as Convolutional Neural Networks (CNNs) are a specialized kind of neural network for processing data that has a known, grid-like topology.
2. Convolutional neural network indicates that the network employs a mathematical operation called convolution.
3. Convolution is a specialized kind of linear operation.
4. Convolutional networks are simply neural networks that use convolution in place of general matrix multiplication in at least one of their layers.
5. CNNs, (ConvNets), are quite similar to regular neural networks.
6. They are still made up of neurons with weights that can be learned from data. Each neuron receives some inputs and performs a dot product.
7. They still have a loss function on the last fully connected layer.
8. They can still use a non-linearity function a regular neural network receives input data as a single vector and passes through a series of hidden layers.

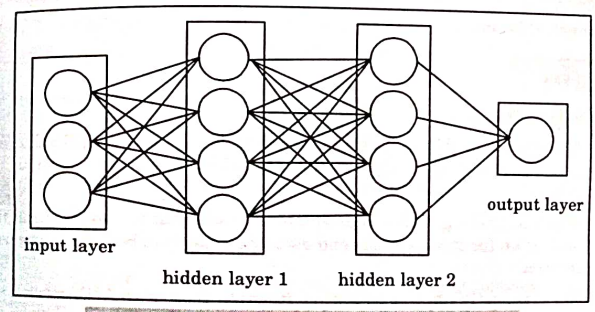


Fig. 4.28.1. A regular three-layer neural network.

9. Every hidden layer consists of neurons, wherein every neuron is fully connected to all the other neurons in the previous layer.
10. Within a single layer, each neuron is completely independent and they do not share any connections.
11. The fully connected layer, (the output layer), contains class scores in the case of an image classification problem. There are three main layers in a simple ConvNet.

Que 4.29. **Write short note on convolutional layer.**

Answer

1. Convolutional layers are the major building blocks used in convolutional neural networks.
2. A convolution is the simple application of a filter to an input that results in an activation.
3. Repeated application of the same filter to an input results in a map of activations called a feature map, indicating the locations and strength of a detected feature in an input, such as an image.
4. The innovation of convolutional neural networks is the ability to automatically learn a large number of filters in parallel specific to a training dataset under the constraints of a specific predictive modeling problem, such as image classification.
5. The result is highly specific features that can be detected anywhere on input images.

Que 4.30. **Describe briefly activation function, pooling and fully connected layer.**

Answer

Activation function :

1. An activation function is a function that is added into an artificial neural network in order to help the network learn complex patterns in the data.
2. When comparing with a neuron-based model that is in our brains, the activation function is at the end deciding what is to be fired to the next neuron.
3. That is exactly what an activation function does in an ANN as well.
4. It takes in the output signal from the previous cell and converts it into some form that can be taken as input to the next cell.

Pooling layer :

1. A pooling layer is a new layer added after the convolutional layer. Specifically, after a non-linearity (for example ReLU) has been applied to the feature maps output by a convolutional layer, for example, the layers in a model may look as follows :
   a. Input image
   b. Convolutional layer

   c. Non-linearity
   d. Pooling layer
2. The addition of a pooling layer after the convolutional layer is a common pattern used for ordering layers within a convolutional neural network that may be repeated one or more times in a given model.
3. The pooling layer operates upon each feature map separately to create a new set of the same number of pooled feature maps.

Fully connected layer :

1. Fully connected layers are an essential component of Convolutional Neural Networks (CNNs), which have been proven very successful in recognizing and classifying images for computer vision.
2. The CNN process begins with convolution and pooling, breaking down the image into features, and analyzing them independently.
3. The result of this process feeds into a fully connected neural network structure that drives the final classification decision.

PART-5

Concept of Convolution (1D and 2D) Layers, Training of Network, Case Study of CNN for eg on Diabetic Retinopathy, Building a Smart Speaker, Self Deriving Car etc.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.31. **Explain 1D and 2D convolutional neural network.**

Answer

1D convolutional neural network :

1. Convolutional Neural Network (CNN) models were developed for image classification, in which the model accepts a two-dimensional input representing an image's pixels and color channels, in a process called feature learning.

2. This same process can be applied to one-dimensional sequences of data.
3. The model extracts features from sequences data and maps the internal features of the sequence.
4. A 1D CNN is very effective for deriving features from a fixed-length segment of the overall dataset, where it is not so important where the feature is located in the segment.
5. 1D Convolutional Neural Networks work well for :
   a. Analysis of a time series of sensor data.
   b. Analysis of signal data over a fixed-length period, for example, an audio recording.
   c. Natural Language Processing (NLP), although Recurrent Neural Networks which leverage Long Short Term Memory (LSTM) cells are more promising than CNN as they take into account the proximity of words to create trainable patterns.

2D convolutional neural network :

1. In a 2D convolutional network, each pixel within the image is represented by its x and y position as well as the depth, representing image channels (red, green, and blue).
2. It moves over the images both horizontally and vertically.

Que 4.32. How we trained a network ? Explain.

Answer

1. Once a network has been structured for a particular application, that network is ready to be trained.
2. To start this process the initial weights are chosen randomly. Then, the training, or learning begins.
3. There are two approaches to training :
   a. In supervised training, both the inputs and the outputs are provided. The network then processes the inputs and compares its resulting outputs against the desired outputs.
   b. Errors are then propagated back through the system, causing the system to adjust the weights which control the network. This process occurs over and over as the weights are continually tweaked.
   c. The set of data which enables the training is called the "training set." During the training of a network the same set of data is processed many times as the connection weights are ever refined.

   d. The other type of training is called unsupervised training. In unsupervised training, the network is provided with inputs but not with desired outputs.
   e. The system itself must then decide what features it will use to group the input data. This is often referred to as self-organization or adaption.

Que 4.33. Describe diabetic retinopathy on the basis of deep learning.

Answer

1. Diabetic Retinopathy (DR) is one of the major causes of blindness in the western world. Increasing life expectancy, indulgent lifestyles and other contributing factors mean the number of people with diabetes is projected to continue rising.
2. Regular screening of diabetic patients for DR has been shown to be a cost-effective and important aspect of their care.
3. The accuracy and timing of this care is of significant importance to both the cost and effectiveness of treatment.
4. If detected early enough, effective treatment of DR is available; making this a vital process.
5. Classification of DR involves the weighting of numerous features and the location of such features. This is highly time consuming for clinicians.
6. Computers are able to obtain much quicker classifications once trained, giving the ability to aid clinicians in real-time classification.
7. The efficacy of automated grading for DR has been an active area of research in computer imaging with encouraging conclusions.
8. Significant work has been done on detecting the features of DR using automated methods such a support vector machines and k-NN classifiers.
9. The majority of these classification techniques arc on two class classification for DR or no DR.

Que 4.34. Using artificial neural network how we recognize speaker.

Answer

1. With the technology advancements in smart home sector, voice control and automation are key components that can make a real difference in people's lives.

2. The voice recognition technology market continues to involve rapidly as almost all smart home devices are providing speaker recognition capability today.
3. However, most of them provide cloud-based solutions or use very deep Neural Networks for speaker recognition task, which are not suitable models to run on smart home devices.
4. Here, we compare relatively small Convolutional Neural Networks (CNN) and evaluate effectiveness of speaker recognition using these models on edge devices. In addition, we also apply transfer learning technique to deal with a problem of limited training data.
5. By developing solution suitable for running inference locally on edge devices, we eliminate the well-known cloud computing issues, such as data privacy and network latency, etc.
6. The preliminary results proved that the chosen model adapts the benefit of computer vision task by using CNN and spectrograms to perform speaker classification with precision and recall ~ 84 % in time less than 60 ms on mobile device with Atom Cherry Trail processor.

Que 4.35. Artificial intelligence plays important role in self-driving car explain.

Answer

1. The rapid development of the Internet economy and Artificial Intelligence (AI) has promoted the progress of self-driving cars.
2. The market demand and economic value of self-driving cars are increasingly prominent. At present, more and more enterprises and scientific research institutions have invested in this field. Google, Tesla, Apple, Nissan, Audi, General Motors, BMW, Ford, Honda, Toyota, Mercedes, and Volkswagen have participated in the research and development of self-driving cars.
3. Google is an Internet company, which is one of the leaders in self-driving cars, based on its solid foundation in artificial intelligence.
4. In June 2015, two Google self-driving cars were tested on the road. So far, Google vehicles have accumulated more than 3.2 million km of tests, becoming the closest to the actual use.
5. Another company that has made great progress in the field of self-driving cars is Tesla. Tesla was the first company to devote self-driving technology to production.

6. Followed by the Tesla models series, its "auto-pilot" technology has made major breakthroughs in recent years.
7. Although the Tesla's autopilot technology is only regarded as Level 2 stage by the National Highway Traffic Safety Administration (NHTSA), Tesla shows us that the car has basically realized automatic driving under certain conditions.

☺☺☺

5 UNIT

Reinforcement Learning and Genetic Algorithm

CONTENTS

PART-1

Introduction to Reinforcement Learning.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.1. Describe reinforcement learning.

Answer

1. Reinforcement learning is the study of how animals and artificial systems can learn to optimize their behaviour in the face of rewards and punishments.
2. Reinforcement learning algorithms related to methods of dynamic programming which is a general approach to optimal control.
3. Reinforcement learning phenomena have been observed in psychological studies of animal behaviour, and in neurobiological investigations of neuromodulation and addiction.
4. The task of reinforcement learning is to use observed rewards to learn an optimal policy for the environment. An optimal policy is a policy that maximizes the expected total reward.
5. Without some feedback about what is good and what is bad, the agent will have no grounds for deciding which move to make.
6. The agents needs to know that something good has happened when it wins and that something bad has happened when it loses.
7. This kind of feedback is called a reward or reinforcement.
8. Reinforcement learning is valuable in the field of robotics, where the tasks to be performed are frequently complex enough to defy encoding as programs and no training data is available.
9. In many complex domains, reinforcement learning is the only feasible way to train a program to perform at high levels.

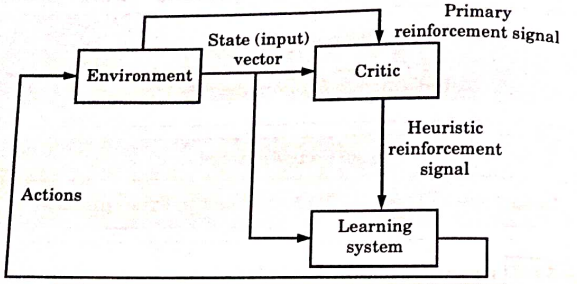


Fig. 5.1.1. Block diagram of reinforcement learning.

Que 5.2. Differentiate between reinforcement and supervised learning.

Answer

S. No.	Reinforcement learning	Supervised learning
1.	Reinforcement learning is all about making decisions sequentially. In simple words we can say that the output depends on the state of the current input and the next input depends on the output of the previous input.	In supervised learning, the decision is made on the initial input or the input given at the start.
2.	In reinforcement learning decision is dependent. So, we give labels to sequences of dependent decisions.	Supervised learning decisions are independent of each other so labels are given to each decision.
3.	**Example :** Chess game.	**Example :** Object recognition.

Que 5.3. What is reinforcement learning ? Explain passive reinforcement learning and active reinforcement learning.

Answer

Reinforcement learning : Refer Q. 5.1, Page 5–2L, Unit-5.

Passive reinforcement learning :

1. In passive learning, the agent's policy π is fixed. In state s, it always executes the action $\pi(s)$.
2. Its goal is simply to learn how good the policy is – that is, to learn the utility function $U^{\pi}(s)$.
3. Fig. 5.3.1 shows a policy for the world and the corresponding utilities.
4. In Fig. 5.3.1(*a*) the policy happens to be optimal with rewards of $R(s) = -0.04$ in the non-terminal states and no discounting.
5. Passive learning agent does not know the transition model $T(s, a, s')$, which specifies the probability of reaching state s' from state s after doing action a; nor does it know the reward function $R(s)$ which specifies the reward for each state.
6. The agent executes a set of trials in the environment using its policy π.
7. In each trial, the agent starts in state (1, 1) and experiences a sequence of state transitions until it reaches one of the terminal states, (4, 2) or (4, 3).
8. Its percepts supply both the current state and the reward received in that state. Typical trials might look like this.

$(1,1)_{-0.04} \rightarrow (1,2)_{-0.04} \rightarrow (1,3)_{-0.04} \rightarrow (1,2)_{-0.04} \rightarrow (1,3)_{-0.04} \rightarrow (2,3)_{-0.04} \rightarrow (3,3)_{-0.04} \rightarrow (4,3)_{+1}$
$(1,1)_{-0.04} \rightarrow (1,2)_{-0.04} \rightarrow (1,3)_{-0.04} \rightarrow (2,3)_{-0.04} \rightarrow (3,3)_{-0.04} \rightarrow (3,2)_{-0.04} \rightarrow (3,3)_{-0.04} \rightarrow (4,3)_{+1}$
$(1,1)_{-0.04} \rightarrow (2,1)_{-0.04} \rightarrow (3,1)_{-0.04} \rightarrow (3,2)_{-0.04} \rightarrow (4,2)_{-1}$

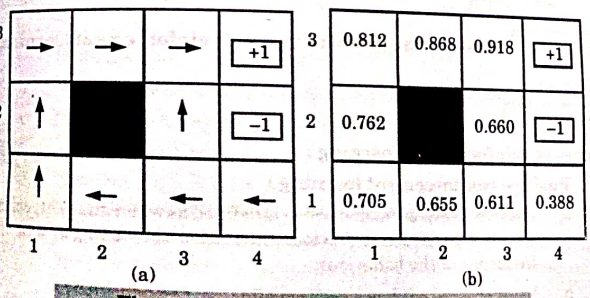


Fig. 5.3.1. (a) A policy π for the 4 × 3 world; (b) The utilities of the states in the 4 × 3 world, given policy π.

9. Each state percept is subscripted with the reward received. The object is to use the information about rewards to learn the expected utility $U^{\pi}(s)$ associated with each non-terminal state s.
10. The utility is defined to be the expected sum of (discounted) rewards obtained if policy π is followed :

$$U^{\pi}(s) = E\left[\sum_{t=0}^{\infty} \gamma^t R(s_t) \mid \pi, s_0 = s\right]$$

where γ is a discount factor, for the 4 × 5 world we set $\gamma = 1$.

Active reinforcement learning :

1. An active agent must decide what actions to take.
2. First, the agent will need to learn a complete model with outcome probabilities for all actions, rather than just model for the fixed policy.
3. We need to take into account the fact that the agent has a choice of actions.
4. The utilities it needs to learn are those defined by the optimal policy, they obey the Bellman equations :

$$U(S) = R(S) + \gamma \max_{a} \sum_{s'} T(s, a, s') U(s')$$

5. These equations can be solved to obtain the utility function U using the value iteration or policy iteration algorithms.
6. A utility function U is optimal for the learned model, the agent can extract an optimal action by one-step look-ahead to maximize the expected utility.
7. Alternatively, if it uses policy iteration, the optimal policy is already available, so it should simply execute the action the optimal policy recommends.

Que 5.4. **What are the different types of reinforcement learning? Explain.**

Answer

Types of reinforcement learning :

1. **Positive reinforcement learning :**
   a. Positive reinforcement learning is defined as when an event, occurs due to a particular behaviour, increases the strength and the frequency of the behaviour.
   b. In other words, it has a positive effect on the behaviour.
   c. Advantages of positive reinforcement learning are :
      i. Maximizes performance.
      ii. Sustain change for a long period of time.
   d. Disadvantages of positive reinforcement learning :
      i. Too much reinforcement can lead to overload of states which can diminish the results.
2. **Negative reinforcement learning :**
   a. Negative reinforcement is defined as strengthening of behaviour because a negative condition is stopped or avoided.

   b. Advantages of negative reinforcement learning :
      i. Increases behaviour.
      ii. It provide defiance to minimum standard of performance.
   c. Disadvantages of negative reinforcement learning :
      i. It only provides enough to meet up the minimum behaviour.

Que 5.5. **What are the elements of reinforcement learning?**

Answer

Elements of reinforcement learning :

1. **Policy (π) :**
   a. It defines the behaviour of the agent which action to take in a given state to maximize the received reward in the long term.
   b. It stimulus-response rules or associations.
   c. It could be a simple lookup table or function, or need more extensive computation (for example, search).
   d. It can be probabilistic.
2. **Reward function (r) :**
   a. It defines the goal in a reinforcement learning problem, maps a state or action to a scalar number, the reward (or reinforcement).
   b. The RL agent's objective is to maximize the total reward it receives in the long run.
   c. It defines good and bad events.
   d. It cannot be altered by the agent but may inform change of policy.
   e. It can be probabilistic (expected reward).
3. **Value function (V) :**
   a. It defines the total amount of reward an agent can expect to accumulate over the future, starting from that state.
   b. A state may yield a low reward but have a high value (or the opposite). For example, immediate pain/pleasure vs. long term happiness.
4. **Transition model (M) :**
   a. It defines the transitions in the environment action a taken in the states, will lead to state s^2.
   b. It can be probabilistic.

PART-2

Learning Task, Example of Reinforcement Learning in Practice.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.6. **Describe briefly learning task used in machine learning.**

Answer

1. A machine learning task is the type of prediction or inference being made, based on the problem or question that is being asked, and the available data.
2. For example, the classification task assigns data to categories, and the clustering task groups data according to similarity.
3. Machine learning tasks rely on patterns in the data rather than being explicitly programmed.
4. A supervised machine learning task that is used to predict which of two classes (categories) an instance of data belongs to.
5. The input of a classification algorithm is a set of labeled examples, where each label is an integer of either 0 or 1.
6. The output of a binary classification algorithm is a classifier, which we can use to predict the class of new unlabeled instances.
7. An unsupervised machine learning task that is used to group instances of data into clusters that contain similar characteristics.
8. Clustering can also be used to identify relationships in a dataset that we might not logically derive by browsing or simple observation.
9. The inputs and outputs of a clustering algorithm depend on the methodology chosen.

Que 5.7. **Explain different machine learning task.**

Answer

Following are most common machine learning tasks :

1. **Data preprocessing :** Before starting training the models, it is important to prepare data appropriately. As part of data preprocessing following is done :
   a. Data cleaning
   b. Handling missing data
2. **Exploratory data analysis :** Once data is preprocessed, the next step is to perform exploratory data analysis to understand data distribution and relationship between / within the data.

3. **Feature engineering / selection :** Feature selection is one of the critical tasks which would be used when building machine learning models. Feature selection is important because selecting right features would not only help build models of higher accuracy but also help achieve objectives related to building simpler models, reduce overfitting etc.
4. **Regression :** Regression tasks deal with estimation of numerical values (continuous variables). Some of the examples include estimation of housing price, product price, stock price etc.
5. **Classification :** Classification task is related with predicting a category of a data (discrete variables). Most common example is predicting whether or not an email is spam or not, whether a person is suffering from a particular disease or not, whether a transaction is fraud or not, etc.
6. **Clustering :** Clustering tasks are all about finding natural groupings of data and a label associated with each of these groupings (clusters). Some of the common example includes customer segmentation, product features identification for product roadmap.
7. **Multivariate querying :** Multivariate querying is about querying or finding similar objects.
8. **Density estimation :** Density estimation problems are related with finding likelihood or frequency of objects.
9. **Dimension reduction :** Dimension reduction is the process of reducing the number of random variables under consideration, and can be divided into feature selection and feature extraction.
10. **Model algorithm / selection :** Many a times, there are multiple models which are trained using different algorithms. One of the important task is to select most optimal models for deploying them in production.
11. **Testing and matching :** Testing and matching tasks relates to comparing data sets.

Que 5.8. **Explain reinforcement learning with the help of an example.**

Answer

1. Reinforcement learning (RL) is learning concerned with how software agents ought to take actions in an environment in order to maximize the notion of cumulative reward.
2. The software agent is not told which actions to take, but instead must discover which actions yield the most reward by trying them.

For example,

Consider the scenario of teaching new tricks to a cat :

1. As cat does not understand English or any other human language, we cannot tell her directly what to do. Instead, we follow a different strategy.

2. We emulate a situation, and the cat tries to respond in many different ways. If the cat's response is the desired way, we will give her fish.
3. Now whenever the cat is exposed to the same situation, the cat executes a similar action even more enthusiastically in expectation of getting more reward (food).
4. That's like learning that cat gets from "what to do" from positive experiences.
5. At the same time, the cat also learns what not do when faced with negative experiences.

Working of reinforcement learning :

1. In this case, the cat is an agent that is exposed to the environment (In this case, it is your house). An example of a state could be our cat sitting, and we use a specific word in for cat to walk.
2. Our agent reacts by performing an action transition from one "state" to another "state."
3. For example, the cat goes from sitting to walking.
4. The reaction of an agent is an action, and the policy is a method of selecting an action given a state in expectation of better outcomes.
5. After the transition, they may get a reward or penalty in return.

PART-3

Learning Models for Reinforcement (Markov Decision Process, Q Learning, Q Learning Function, Q Learning Algorithm), Application of Reinforcement Learning.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.9. **Describe important term used in reinforcement learning method.**

Answer

Following are the terms used in reinforcement learning :

Agent : It is an assumed entity which performs actions in an environment to gain some reward.

i. **Environment (e) :** A scenario that an agent has to face.

ii. **Reward (R) :** An immediate return given to an agent when he or she performs specific action or task.

iii. **State (s) :** State refers to the current situation returned by the environment.

iv. **Policy (π) :** It is a strategy which applies by the agent to decide the next action based on the current state.

v. **Value (V) :** It is expected long-term return with discount, as compared to the short-term reward.

vi. **Value Function :** It specifies the value of a state that is the total amount of reward. It is an agent which should be expected beginning from that state.

vii. **Model of the environment :** This mimics the behavior of the environment. It helps you to make inferences to be made and also determine how the environment will behave.

viii. **Model based methods :** It is a method for solving reinforcement learning problems which use model-based methods.

ix. **Q value or action value (Q) :** Q value is quite similar to value. The only difference between the two is that it takes an additional parameter as a current action.

Que 5.10. **Explain approaches used to implement reinforcement learning algorithm.**

Answer

There are three approaches used implement a reinforcement learning algorithm :

1. **Value-Based :**

a. In a value-based reinforcement learning method, we should try to maximize a value function V(s). In this method, the agent is expecting a long-term return of the current states under policy π.

2. **Policy-based :**

a. In a policy-based RL method, we try to come up with such a policy that the action performed in every state helps you to gain maximum reward in the future.

b. Two types of policy-based methods are :

i. **Deterministic :** For any state, the same action is produced by the policy π.

ii. **Stochastic :** Every action has a certain probability, which is determined by the following equation stochastic policy :

$$n(a/s) = P/A = a/S = S$$

3. **Model-Based :**

a. In this Reinforcement Learning method, we need to create a virtual model for each environment.

b. The agent learns to perform in that specific environment.

Que 5.11. Describe learning models of reinforcement learning.

Answer

1. Reinforcement learning is defined by a specific type of problem, and all its solutions are classed as reinforcement learning algorithms.
2. In the problem, an agent is supposed to decide the best action to select based on his current state.
3. When this step is repeated, the problem is known as a Markov Decision Process.
4. A Markov Decision Process (MDP) model contains :

a. A State is a set of tokens that represent every state that the agent can be in.

b. A Model (sometimes called Transition Model) gives an action's effect in a state. In particular, T(S, a, S') defines a transition T where being in state S and taking an action 'a' takes us to state S' (S and S' may be same).

c. An Action A is set of all possible actions. A(s) defines the set of actions that can be taken being in state S.

d. A Reward is a real-valued reward function. R(s) indicates the reward for simply being in the state S. R(S,a) indicates the reward for being in a state S and taking an action 'a'. R(S,a,S') indicates the reward for being in a state S, taking an action 'a' and ending up in a state S'.

e. A Policy is a solution to the Markov Decision Process. A policy is a mapping from S to a. It indicates the action 'a' to be taken while in state S.

Que 5.12. What are the application of reinforcement learning and why we use reinforcement learning ?

Answer

Following are the applications of reinforcement learning :

1. Robotics for industrial automation.
2. Business strategy planning.
3. Machine learning and data processing.
4. It helps us to create training systems that provide custom instruction and materials according to the requirement of students.
5. Aircraft control and robot motion control.

Following are the reasons for using reinforcement learning :

1. It helps us to find which situation needs an action.
2. Helps us to discover which action yields the highest reward over the longer period.

3. Reinforcement Learning also provides the learning agent with a reward function.
4. It also allows us to figure out the best method for obtaining large rewards.

Que 5.13. When not to use reinforcement learning ? What are the challenges of reinforcement learning ?

Answer

We cannot apply reinforcement learning model is all the situation. Following are the conditions when we should not use reinforcement learning model.

1. When we have enough data to solve the problem with a supervised learning method.
2. When the action space is large reinforcement learning is computing heavy and time-consuming.

Challenges we will face while doing reinforcement learning are :

1. Feature/reward design which should be very involved.
2. Parameters may affect the speed of learning.
3. Realistic environments can have partial observability.
4. Too much reinforcement may lead to an overload of states which can diminish the results.
5. Realistic environments can be non-stationary.

Que 5.14. Explain the term Q-learning.

Answer

1. Q-learning is a model-free reinforcement learning algorithm.
2. Q-learning is a values-based learning algorithm. Value based algorithms updates the value function based on an equation (particularly Bellman equation).
3. Whereas the other type, policy-based estimates the value function with a greedy policy obtained from the last policy improvement.
4. Q-learning is an off-policy learner *i.e.*, it learns the value of the optimal policy independently of the agent's actions.
5. On the other hand, an on-policy learner learns the value of the policy being carried out by the agent, including the exploration steps and it will find a policy that is optimal, taking into account the exploration inherent in the policy.

Que 5.15. Describe Q-learning algorithm process.

Answer

Step 1 : Initialize the Q-table : First the Q-table has to be built. There are n columns, where n = number of actions. There are m rows, where m = number of states.

In our example n = Go left, Go right, Go up and Go down and m = Start, Idle, Correct path, Wrong path and End. First, lets initialize the value at 0.

Step 2 : Choose an action.

Step 3 : Perform an action : The combination of steps 2 and 3 is performed for an undefined amount of time. These steps run until the time training is stopped, or when the training loop stopped as defined in the code.

a. First, an action (a) in the state (s) is chosen based on the Q-table. Note that, when the episode initially starts, every Q-value should be 0.

b. Then, update the Q-values for being at the start and moving right using the Bellman equation.

Step 4 : Measure reward : Now we have taken an action and observed an outcome and reward.

Step 5 : Evaluate : We need to update the function Q(s, a)

This process is repeated again and again until the learning is stopped. In this way the Q-table is been updated and the value function Q is maximized. Here the Q returns the expected future reward of that action at that state.

PART-4

Introduction to Deep Q Learning.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.16. Describe deep Q-learning.

Answer

1. In deep Q-learning, we use a neural network to approximate the Q-value function.
2. The state is given as the input and the Q-value of all possible actions is generated as the output.
3. The comparison between Q-learning and deep Q-learning is illustrated below :

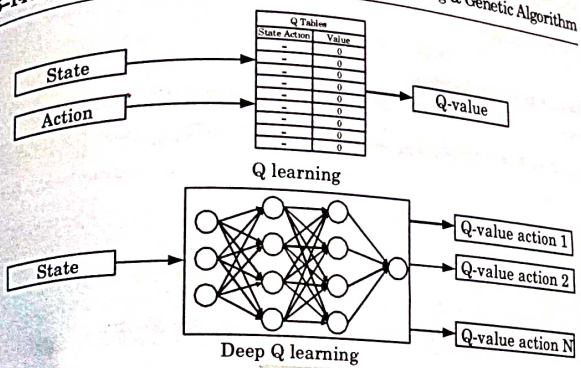


Fig. 5.16.1.

4. On a higher level, Deep Q learning works as such :
   i. Gather and store samples in a replay buffer with current policy.
   ii. Random sample batches of experiences from the replay buffer.
   iii. Use the sampled experiences to update the Q network.
   iv. Repeat 1-3.

Que 5.17. What are the steps involved in deep Q-learning network ?

Answer

Steps involved in reinforcement learning using deep Q-learning networks :

1. All the past experience is stored by the user in memory.
2. The next action is determined by the maximum output of the Q-network.
3. The loss function here is mean squared error of the predicted Q-value and the target Q-value – Q*. This is basically a regression problem.
4. However, we do not know the target or actual value here as we are dealing with a reinforcement learning problem. Going back to the Q-value update equation derived from the Bellman equation, we have :

$$Q(S_t, A_t) \leftarrow Q(S_t, A_t) + \alpha[R_{t+1} + \gamma \max_a Q(S_{t+1}, a) - Q(S_t, A_t)]$$

Que 5.18. Write pseudocode for deep Q-learning.

Answer

Start with $Q_0(s, a)$ for all s, a.
Get initial state s
For $k = 1, 2, \ldots$ till convergence
Sample action a, get next state s'

If s' is terminal :

$$\text{target} = R(s, a, s')$$

Sample new initial state s'

else $$\text{target} = R(s, a, s') + \gamma \max Q_k(s', a')$$

$$\theta_{k+1} \leftarrow \theta_k - \alpha \nabla_\theta E_{s' \sim P(s'|s,a)}[(Q_\theta(s, a) - \text{target}(s'))^2]|_{\theta = \theta_k}$$

$$s \leftarrow s'$$

PART-5

Genetic Algorithm, Introduction, Components, GA Cycle of Reproduction, Crossover, Mutation, Genetic Programming, Models of Evolution and Learning, Application.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.19. **Write short note on Genetic algorithm.**

Answer

1. Genetic algorithms are computerized search and optimization algorithm based on mechanics of natural genetics and natural selection.
2. These algorithms mimic the principle of natural genetics and natural selection to construct search and optimization procedure.
3. Genetic algorithms convert the design space into genetic space. Design space is a set of feasible solutions.
4. Genetic algorithms work with a coding of variables.
5. The advantage of working with a coding of variables space is that coding discretizes the search space even though the function may be continuous.
6. Search space is the space for all possible feasible solutions of particular problem.
7. Following are the benefits of Genetic algorithm :
   a. They are robust.
   b. They provide optimization over large space state.
   c. They do not break on slight change in input or presence of noise.
8. Following are the application of Genetic algorithm :
   a. Recurrent neural network
   b. Mutation testing
   c. Code breaking
   d. Filtering and signal processing
   e. Learning fuzzy rule base

Que 5.20. **Write procedure of Genetic algorithm with advantages and disadvantages.**

Answer

Procedure of Genetic algorithm :

1. Generate a set of individuals as the initial population.
2. Use genetic operators such as selection or cross over.
3. Apply mutation or digital reverse if necessary.
4. Evaluate the fitness function of the new population.
5. Use the fitness function for determining the best individuals and replace predefined members from the original population.
6. Iterate steps 2–5 and terminate when some predefined population threshold is met.

Advantages of genetic algorithm :

1. Genetic algorithms can be executed in parallel. Hence, genetic algorithms are faster.
2. It is useful for solving optimization problems.

Disadvantages of Genetic algorithm :

1. Identification of the fitness function is difficult as it depends on the problem.
2. The selection of suitable genetic operators is difficult.

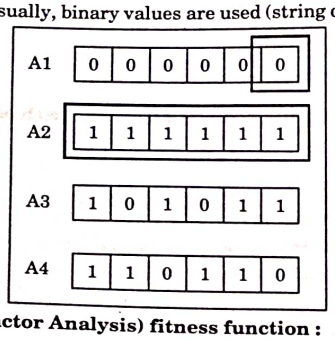
Que 5.21. **Explain different phases of genetic algorithm.**

Answer

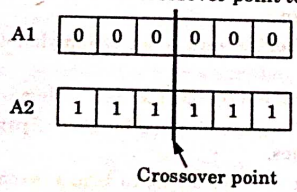
Different phases of genetic algorithm are :

1. **Initial population :**
   a. The process begins with a set of individuals which is called a population.
   b. Each individual is a solution to the problem we want to solve.
   c. An individual is characterized by a set of parameters (variables) known as genes.
   d. Genes are joined into a string to form a chromosome (solution).
   e. In a genetic algorithm, the set of genes of an individual is represented using a string.

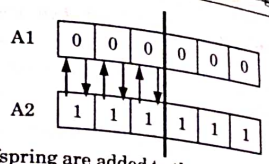
f. Usually, binary values are used (string of 1s and 0s).



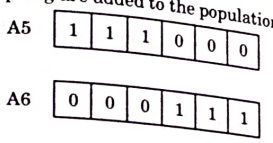
2. **FA (Factor Analysis) fitness function :**
   a. The fitness function determines how fit an individual is (the ability of all individual to compete with other individual).
   b. It gives a fitness score to each individual.
   c. The probability that an individual will be selected for reproduction is based on its fitness score.
3. **Selection :**
   a. The idea of selection phase is to select the fittest individuals and let them pass their genes to the next generation.
   b. Two pairs of individuals (parents) are selected based on their fitness scores.
   c. Individuals with high fitness have more chance to be selected for reproduction.
4. **Crossover :**
   a. Crossover is the most significant phase in a genetic algorithm.
   b. For each pair of parents to be mated, a crossover point is chosen at random from within the genes.
   c. For example, consider the crossover point to be 3 as shown :



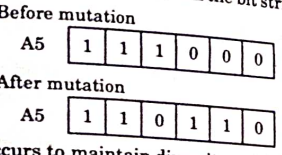
   d. Offspring are created by exchanging the genes of parents among themselves until the crossover point is reached.



   e. The new offspring are added to the population.



5. **Mutation :**
   a. When new offspring formed, some of their genes can be subjected to a mutation with a low random probability.
   b. This implies that some of the bits in the bit string can be flipped.



   c. Mutation occurs to maintain diversity within the population and prevent premature convergence.
6. **Termination :**
   a. The algorithm terminates if the population has converged (does not produce offspring which are significantly different from the previous generation).
   b. Then it is said that the genetic algorithm has provided a set of solutions to our problem.

Que 5.22. Draw a flowchart of GA and explain the working principle.

Answer

Genetic algorithm : Refer Q. 1.24, Page 1–23L, Unit-1.

Working principle :

1. To illustrate the working principle of GA, we consider unconstrained optimization problem.
2. Let us consider the following maximization problem :

   maximize $f(X)$

   $X_i^{(L)} \le X_i \le X_i^{(U)}$ for $i = 1, 2 \ldots N$,

3. If we want to minimize $f(X)$, for $f(X) > 0$, then we can write the objective function as :

$$\text{maximize } \frac{1}{1+f(X)}$$

4. If $f(X) < 0$ instead of minimizing $f(X)$, maximize $(-f(X))$. Hence, both maximization and minimization problems can be handled by GA.

Que 5.23. Write short notes on procedures of GA.

Answer

1. **Start :** Generate random population of n chromosomes.
2. **Fitness :** Evaluate the fitness $f(x)$ of each chromosome x in the population.
3. **New population :** Create a new population by repeating following steps until the new population is complete.
   a. **Selection :** Select two parent chromosomes from a population according to their fitness.
   b. **Crossover :** With a crossover probability crossover the parents to form new offspring (children). If no crossover was performed, offspring is the exact copy of parents.
   c. **Mutation :** With a mutation probability mutate new offspring at each locus (position in chromosome).
   d. **Accepting :** Place new offspring in the new population.
4. **Replace :** Use new generated population for a further run of the algorithm.
5. **Test :** If the end condition is satisfied, stop, and return the best solution in current population.
6. Go to step 2

Que 5.24. What are the benefits of using GA ? What are its limitations ?

Answer

Benefits of using GA :

1. It is easy to understand.
2. It is modular and separate from application.
3. It supports multi-objective optimization.
4. It is good for noisy environment.

Limitations of genetic algorithm are :

1. The problem of identifying fitness function.

2. Definition of representation for the problem.
3. Premature convergence occurs.
4. The problem of choosing the various parameters like the size of the population, mutation rate, crossover rate, the selection method and its strength.
5. Cannot use gradients.
6. Cannot easily incorporate problem specific information.
7. Not good at identifying local optima.
8. No effective terminator.
9. Not effective for smooth unimodal functions.
10. Needs to be coupled with a local search technique.

Que 5.25. Write short notes of genetic representations.

Answer

1. Genetic representation is a way of representing solutions/individuals in evolutionary computation methods.
2. Genetic representation can encode appearance, behavior, physical qualities of individuals.
3. All the individuals of a population are represented by using binary encoding, permutational encoding, encoding by tree.
4. Genetic algorithms use linear binary representations. The most standard method of representation is an array of bits.
5. These genetic representations are convenient because parts of individual are easily aligned due to their fixed size which makes simple crossover operation.

Que 5.26. Give the detail of genetic representation (Encoding).

OR

Explain different types of encoding in genetic algorithm.

Answer

Genetic representations :

1. **Encoding :**
   a. Encoding is a process of representing individual genes.
   b. The process can be performed using bits, numbers, trees, arrays, lists or any other objects.
   c. The encoding depends mainly on solving the problem.
2. **Binary encoding :**
   a. Binary encoding is the most commonly used method of genetic representation because GA uses this type of encoding.

b. In binary encoding, every chromosome is a string of bits, 0 or 1.

Chromosome A	10110010110010101100101
Chromosome B	11111110000011000001111

c. Binary encoding gives many possible chromosomes.

3. **Octal or Hexadecimal encoding :**

a. The encoding is done using octal or hexadecimal numbers.

Chromosome	Octal	Hexadecimal
Chromosome A	54545345	B2CAE5
Chromosome B	77406037	FE0C1F

4. **Permutation encoding (real number encoding) :**

a. Permutation encoding can be used in ordering problems, such as Travelling Salesman Problem (TSP).

b. In permutation encoding, every chromosome is a string of numbers, which represents number in a sequence.

Chromosome A	1 5 3 2 6 4 7 9 8
Chromosome B	8 5 6 7 2 3 1 4 9

5. **Value encoding :**

a. Direct value encoding can be used in problems, where some complicated values, such as real numbers, are used.

b. In value encoding, every chromosome is a string of some values.

c. Values can be anything connected to problem, real numbers or chars to some complicated objects.

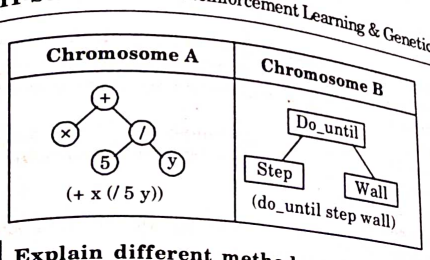
Chromosome A	1.2324 5.3243 0.4556 2.3293 2.4545
Chromosome B	ABDJEIFJDHDIERJFDLDFLFEGT
Chromosome C	(back), (back), (right), (forward), (left)

6. **Tree encoding :**

a. Tree encoding is used for evolving programs or expressions, for genetic programming.

b. In tree encoding, every chromosome is a tree of some objects, such as functions or commands in programming language.

c. Programming language LISP is often used to this, because programs in it are represented in this form and can be easily parsed as a tree, so the cross-over and mutation can be done relatively easily.



Que 5.27. Explain different methods of selection in genetic algorithm in order to select a population for next generation.

Answer

The various methods of selecting chromosomes for parents to cross over are :

a. **Roulette-wheel selection :**

i. Roulette-wheel selection is the proportionate reproductive method where a string is selected from the mating pool with a probability proportional to the fitness.

ii. Thus, ith string in the population is selected with a probability proportional to F_i where F_i is the fitness value for that string.

iii. Since the population size is usually kept fixed in Genetic Algorithm, the sum of the probabilities of each string being selected for the mating pool must be one.

iv. The probability of the ith selected string is

$$p_i = \frac{F_i}{\sum_{j=1}^{n} F_j}$$

where 'n' is the population size.

v. The average fitness is

$$\bar{F} = \sum_{j=1}^{n} F_j / n \qquad \ldots(5.27.1)$$

b. **Boltzmann selection :**

i. Boltzmann selection uses the concept of simulated annealing.

ii. Simulated annealing is a method of functional minimization or maximization.

iii. This method simulates the process of slow cooling of molten metal to achieve the minimum function value in a minimization problem.

iv. The cooling phenomenon is simulated by controlling a temperature so that a system in thermal equilibrium at a temperature T has its energy distributed probabilistically according to

$$P(E) = \exp\left(-\frac{E}{kT}\right) \qquad \ldots(5.27.2)$$

where 'k' is Boltzmann constant.

v. This expression suggests that a system at a high temperature has almost uniform probability of being at any energy state, but at a low temperature it has a small probability of being at a high energy state.

vi. Therefore, by controlling the temperature T and assuming search process follows Boltzmann probability distribution, the convergence of the algorithm is controlled.

c. Tournament selection :

i. GA uses a strategy to select the individuals from population and insert them into a mating pool.

ii. A selection strategy in GA is a process that favours the selection of better individuals in the population for the mating pool.

iii. There are two important issues in the evolution process of genetic search.

1. **Population diversity :** Population diversity means that the genes from the already discovered good individuals are exploited.
2. **Selective pressure :** Selective pressure is the degree to which the better individuals are favoured.

iv. The higher the selective pressure the better individuals are favoured.

d. Rank selection :

i. Rank selection first ranks the population and takes every chromosome, receives fitness from the ranking.

ii. The worst will have fitness 1, the next 2, ..., and the best will have fitness N (N is the number of chromosomes in the population).

iii. The method can lead to slow convergence because the best chromosome does not differ so much from the other.

e. Steady-state selection :

i. The main idea of the selection is that bigger part of chromosome should survive to next generation.

ii. GA works in the following way :

1. In every generation a few chromosomes are selected for creating new off springs.
2. Then, some chromosomes are removed and new offspring is placed in that place.
3. The rest of population survives a new generation.

Que 5.28. Differentiate between Roulette-wheel based on fitness and Roulette-wheel based on rank with suitable example.

Answer

Difference :

S. No.	Roulette-wheel based on fitness	Roulette-wheel based on rank
1.	Population is selected with a probability that is directly proportional to their fitness values.	Probability of a population being selected is based on its fitness rank.
2.	It computes selection probabilities according to their fitness values but do not sort the individual in the population.	It first sort individuals in the population according to their fitness and then computes selection probabilities according to their ranks rather than fitness values.
3.	It gives a chance to all the individuals in the population to be selected.	It selects the individuals with highest rank in the population.
4.	Diversity in the population is preserved.	Diversity in the population is not preserved.

Example :

1. Imagine a Roulette-wheel where all chromosomes in the population are placed, each chromosome has its place accordingly to its fitness function :

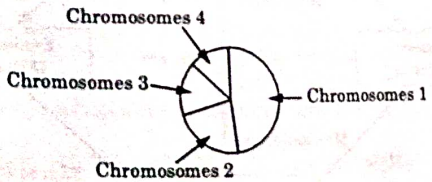


Fig. 5.28.1. Roulette-wheel selection.

2. When the wheel is spun, the wheel will finally stop and pointer attached to it will points to the one of chromosomes with bigger fitness value.
3. The different between roulette-wheel selection based on fitness and rank is shown in Fig. 5.28.1 and Fig. 5.28.3.

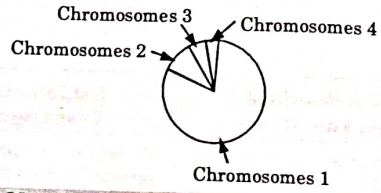


Fig. 5.28.2. Situation before ranking (graph of fitnesses).

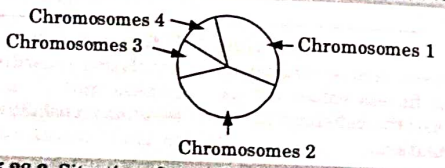


Fig. 5.28.3. Situation after ranking (graph of order numbers).

Que 5.29. Draw genetics cycle for genetic algorithm.

Answer

Generational cycle of GA :

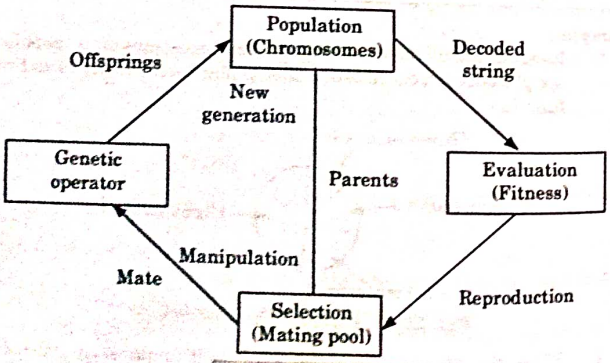


Fig. 5.29.1. The GA cycle.

Components of generational cycle in GA :

1. **Population (Chromosomes) :** A population is collection of individuals. A population consists of a number of individuals being tested, the phenotype parameters defining the individuals and some information about search space.
2. **Evaluation (Fitness) :** A fitness function is a particular type of objective function that quantifies the optimality of a solution (*i.e.*, a chromosome) in a genetic algorithm so that particular chromosome may be ranked against all the other chromosomes.

3. **Selection :** During each successive generation, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a fitness-based process.
4. **Generic operator :** A genetic operator is an operator used in genetic algorithm to guide the algorithm towards a solution to a given problem.

Que 5.30. Why mutation is done in genetic algorithm ? Explain types of mutation.

Answer

Mutation is done in genetic algorithm because :

1. It maintains genetic diversity from one generation of a population of genetic algorithm chromosomes to the next.
2. GA can give better solution of the problem by using mutation.

Types of mutation :

1. **Bit string mutation :** The mutation of bit strings occurs through bit flips at random positions.

   Example : 1 0 1 0 0 1 0

   ↓

   1 0 1 0 1 1 0

   The probability of a mutation of a bit is $1/l$, where l is the length of the binary vector. Thus, a mutation rate of 1 per mutation and individual selected for mutation is reached.
2. **Flip bit :** This mutation operator takes the chosen genome and inverts the bits (*i.e.*, if the genome bit is 1, it is changed to 0 and vice versa).
3. **Boundary :** This mutation operator replaces the genome with either lower or upper bound randomly. This can be used for integer and float genes.
4. **Non-uniform :** The probability that amount of mutation will go to 0 with the next generation is increased by using non-uniform mutation operator. It keeps the population from stagnating in the early stages of the evolution.
5. **Uniform :** This operator replaces the value of the chosen gene with a uniform random value selected between the user-specified upper and lower bounds for that gene.
6. **Gaussian :** This operator adds a unit Gaussian distributed random value to the chosen gene. If it falls outside of the user-specified lower or upper bounds for that gene, the new gene value is clipped.

Que 5.31. What is the main function of crossover operation in genetic algorithm ?

Answer

1. Crossover is the basic operator of genetic algorithm. Performance of genetic algorithm depends on crossover operator.
2. Type of crossover operator used for a problem depends on the type of encoding used.
3. The basic principle of crossover process is to exchange genetic material of two parents beyond the crossover points.

Function of crossover operation/operator in genetic algorithm :

1. The main function of crossover operator is to introduce diversity in the population.
2. Specific crossover made for a specific problem can improve performance of the genetic algorithm.
3. Crossover combines parental solutions to form offspring with a hope to produce better solutions.
4. Crossover operators are critical in ensuring good mixing of building blocks.
5. Crossover is used to maintain balance between exploitation and exploration. The exploitation and exploration techniques are responsible for the performance of genetic algorithms. Exploitation means to use the already existing information to find out the better solution and exploration is to investigate new and unknown solution in exploration space.

Que 5.32. Discuss the different applications of genetic algorithms.

Answer

Application of GA :

1. **Optimization :** Genetic Algorithms are most commonly used in optimization problems wherein we have to maximize or minimize a given objective function value under a given set of constraints.
2. **Economics :** GAs are also used to characterize various economic models like the cobweb model, game theory equilibrium resolution, asset pricing, etc.
3. **Neural networks :** GAs are also used to train neural networks, particularly recurrent neural networks.
4. **Parallelization :** GAs also have very good parallel capabilities, and prove to be very effective means in solving certain problems, and also provide a good area for research.

5. **Image processing :** GAs are used for various digital image processing (DIP) tasks as well like dense pixel matching.
6. **Machine learning :** Genetics based machine learning (GBML) is a nice area in machine learning.
7. **Robot trajectory generation :** GAs have been used to plan the path which a robot arm takes by moving from one point to another.

Que 5.33. Explain optimization of travelling salesman problem using genetic algorithm and give a suitable example too.

Answer

1. The TSP consist a number of cities, where each pair of cities has a corresponding distance.

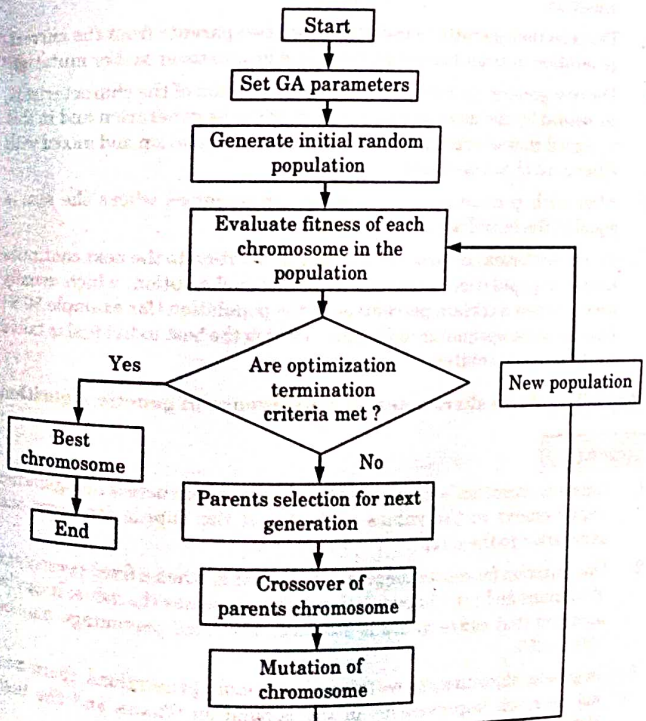


Fig. 5.33.1. Genetic algorithm procedure for TSP.

2. The aim is to visit all the cities such that the total distance travelled will be minimized.
3. A solution, and therefore a chromosome which represents that solution to the TSP, can be given as an order, that is, a path, of the cities.
4. The procedure for solving TSP can be viewed as a process flow given in Fig. 5.33.1.
5. The GA process starts by supplying important information such as location of the city, maximum number of generations, population size, probability of crossover and probability of mutation.
6. An initial random population of chromosomes is generated and the fitness of each chromosome is evaluated.
7. The population is then transformed into a new population (the next generation) using three genetic operators : selection, crossover and mutation.
8. The selection operator is used to choose two parents from the current generation in order to create a new child by crossover and/or mutation.
9. The new generation contains a higher proportion of the characteristics possessed by the good members of the previous generation and in this way good characteristics are spread over the population and mixed with other good characteristics.
10. After each generation, a new set of chromosomes where the size is equal to the initial population size is evolved.
11. This transformation process from one generation to the next continues until the population converges to the optimal solution, which usually occurs when a certain percentage of the population (for example 90 %) has the same optimal chromosome in which the best individual is taken as the optimal solution.

Que 5.34. Write short notes on convergence of genetic algorithm

Answer

1. A genetic algorithm is usually said to converge when there is no significant improvement in the values of fitness of the population from one generation to the next.
2. One criterion for convergence may be such that when a fixed percentage of columns and rows in population matrix becomes the same, it can be assumed that convergence is attained. The fixed percentage may be 80% or 85%.
3. In genetic algorithms as we proceed with more generations, there may not be much improvement in the population fitness and the best individual may not change for subsequent populations.
4. As the generation progresses, the population gets filled with more fit individuals with only slight deviation from the fitness of best individuals

so far found, and the average fitness comes very close to the fitness of the best individuals.

5. The convergence criteria can be explained from schema point of view.
6. A schema is a similarity template describing a subset of strings with similarities at certain positions. A schema represents a subset of all possible strings that have the same bits at certain string positions.
7. Since schema represents a robust of strings, we can associate a fitness value with a schema, *i.e.*, the average fitness of the schema.
8. One can visualize GA's search for the optimal strings as a simultaneous competition among schema increases the number of their instances in the population.

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