Unit - 4

Advanced Learning

Que- Explain the concept of reward and Penalty in reinforcement learning.

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In reinforcement learning (RL), the concepts of reward and penalty are fundamental to how an agent learns to make decisions over time to achieve a desired goal.

1) Reward :-
- A reward is a positive numerical signal given to the agent to reinforce desirable behaviors or actions that lead toward the goal.
- When the agent takes an action in a given state and receives a reward, it interprets that action as beneficial.
- For example, in a game, reaching a checkpoint or completing a level might give the agent a reward encouraging it to take actions that help reach those milestones.

2) Penalty :-
- A penalty is a negative reward or a negative numerical signal given to discourage actions that lead to undesirable outcomes.
- If the agent performs an action that leads to a Penalty, it learns to avoid that action in the future.
- For instance, in a maze-solving task, hitting a wall or going in the wrong direction could incur a Penalty, teaching the agent to avoid these actions.

Role in Learning :-
- The goal of the agent in reinforcement learning is to maximize its total rewards over time. To achieve this, the agent explores various actions and learns from the feedback.
- Using an algorithm like Q-learning or Deep Q-Networks (DQN) the agent estimates the value of each action in each state based on past rewards and penalties.

Balance between Exploitation and Exploration :-
- Rewards and penalties drive the agent's learning process, but the agent must balance exploration (trying new actions) with exploitation (choosing know actions with higher rewards).

Que- Explain Representation Learning

Representation Learning :-
- Representation learning also known as ~~feato~~ feature learning, is a type of machine learning where the algorithm automatically discovers representation or features from raw data that make it easier to perform tasks such as classification, regression or clustering.
- representation learning enables models to learn meaningful patterns and strutures in the data on their own.

Common Techniques in Representation Learning :-

1) Autoencoders :-
- Neural networks that learn to encode data into a compact representation and then decode it back to the original form, useful for dimensionality reduction and anomaly detection

2) Embeddings :-
- Word embeddings in NLP or node embeddings in graph networks map entities to a continuous vector space, capturing relationships in a way that similar entities are closer.

3) Convolutional Neural Networks (CNNs) :-
- Learn spatial hierarchies of features from image data, where earlier layers capture low-level features like edges and deeper layers capture more complex patterns.

4) Graph Neural Networks (GNNs) :-
- Represent data in the form of graphs, capturing relationships and dependencies in data, such as in social networks or molecular structures.

Applications :-
1) Natural Language Processing (NLP)
2) Image Recognition
3) Recommendation systems.

Advantages:-
1) Improved model Performance
2) Hierarchical Feature Learning
3) Better Data utilization
4) Enables Transfer Learning

Disadvantages:-
1) Data and computation Intensive
2) Difficult to Interpret
3) Risk of overfitting
4) Requires Expertise for Tuning

Que- What is neural network and its types.

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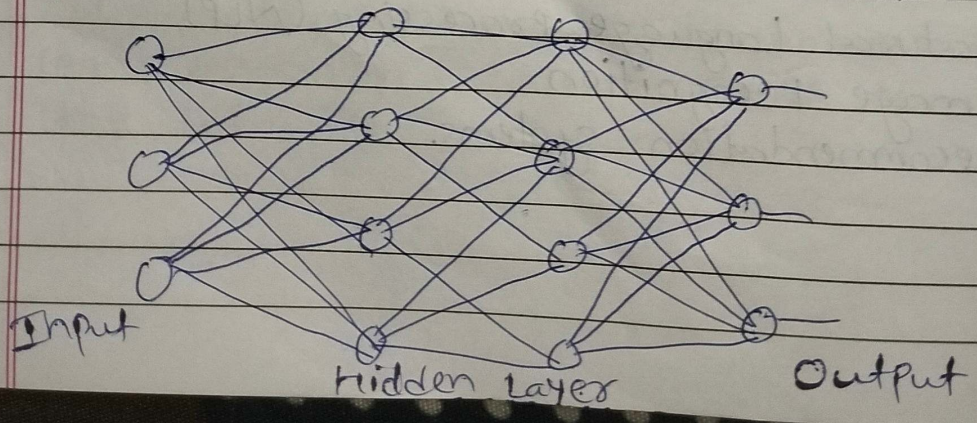
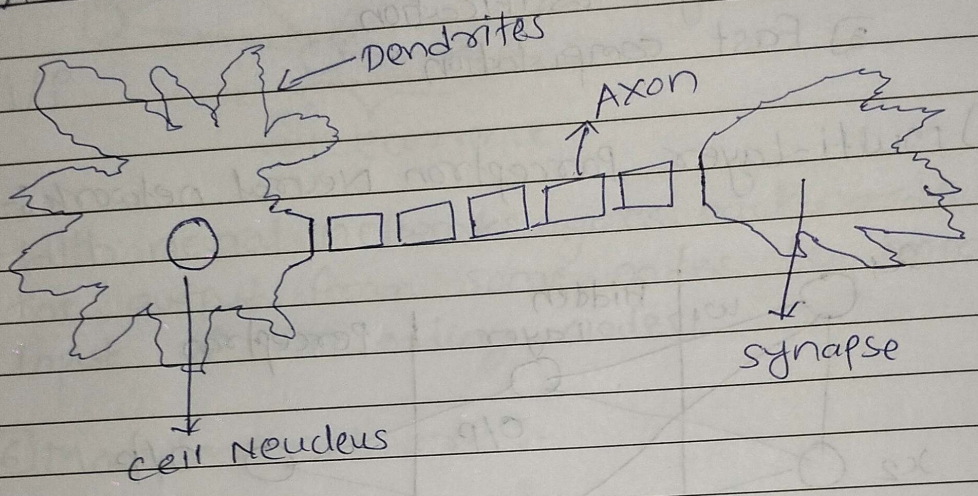
Neural network:-
- A neural network is a machine Learning program or model that makes decisions in a manner similar to the human brain.
- Every neural network consist three Layers - 1) Input Layer
2) Hidden Layer
3) output Layer
- Neural networks works as similar to human brain just in human brain neurouns are interconnected to each other and ANN nodes are interconnected to each other.



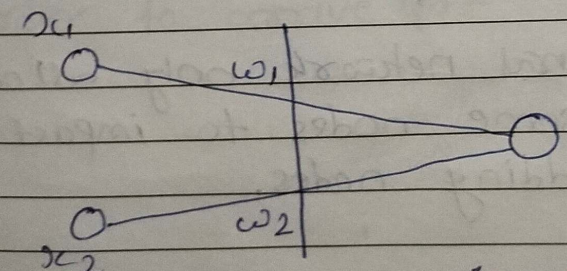
Human	ANN
Dendrites	input
cell Nucleus	Nodes
synopse	weights
Axon	output



Types of Neural Network :-

1) shallo neural Network :-
- shallo neural Network usually have only one hidden Layer over deep neural networks have multiple hidden Layers.
- shallo neural Network fast and low Processing Power.
- shallo networks cannot perform complex task.

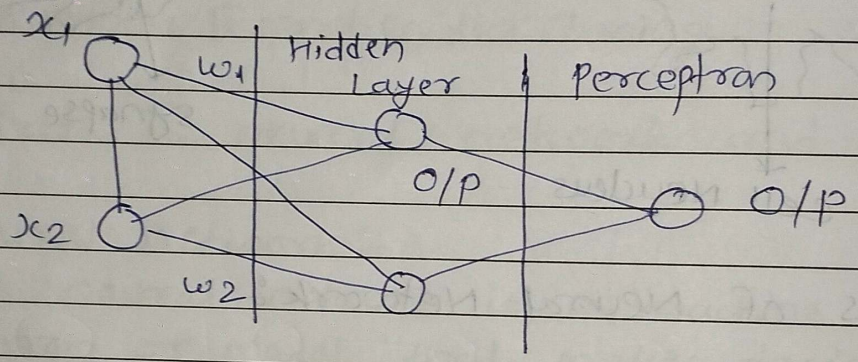
2) Parceptron neural Network



$z = w_1 x_1 + w_2 x_2 \cdots w_n x_n + b$

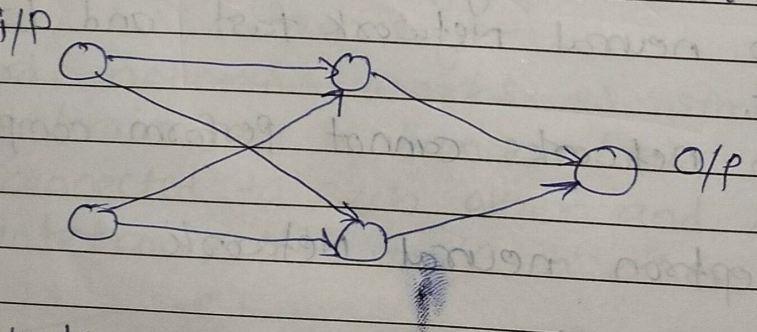
- These network is simple with an input and output Layer most of the network used for binary classification.
- Advantages :-
  1) simple
  2) Binary classification
  3) Fast computation

3) multi-Layer Parceptron Neural network :-



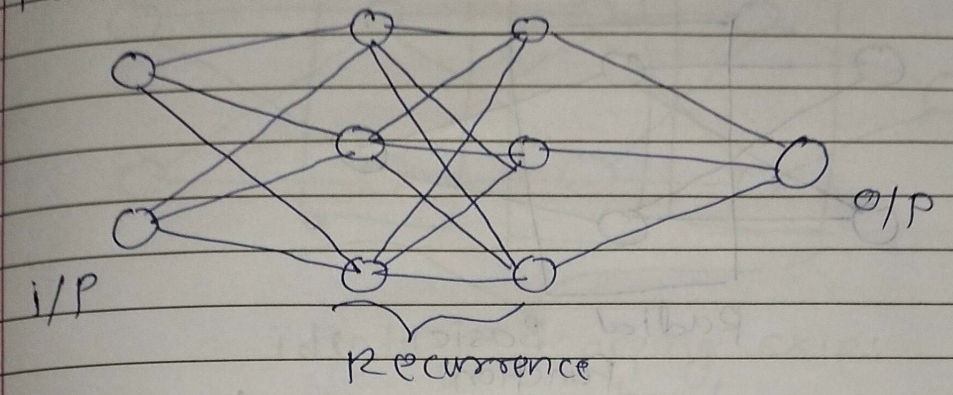
- In these multi-layer perceptron add complexity to neural network includes a hidden layer.

4) Feed - Forward neural network :-



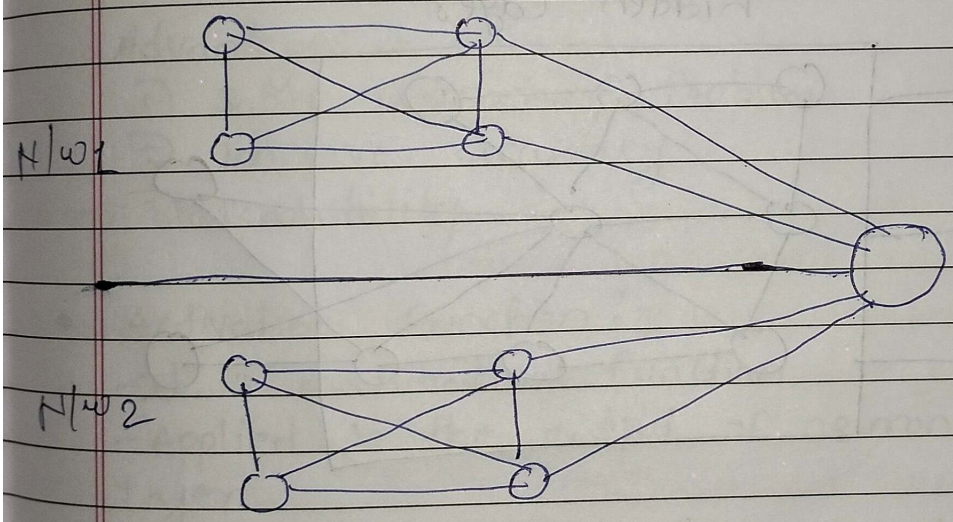
- only these neural network only allow the O/P from some nodes to impact the input of Precedding nodes.

5] Recurrent Neural Network :-



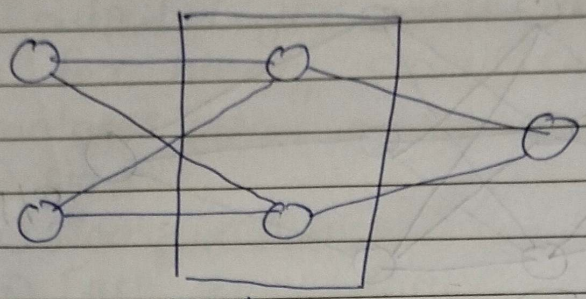
- With neural networks goes backwards allowing the output from some nodes to impact the input of preceding nodes.

6] Modular network :-



- Combine two or more neural network in order to arrive at the output.

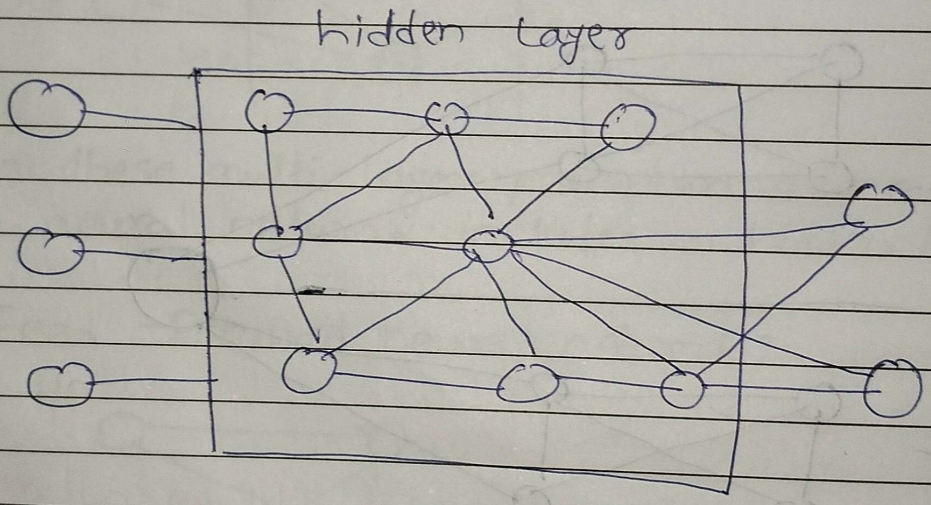
7] Radial basis function network :-



Radial Basic Function

- Neural network nodes use a specific kind of mathematical function called Radial Basis function.

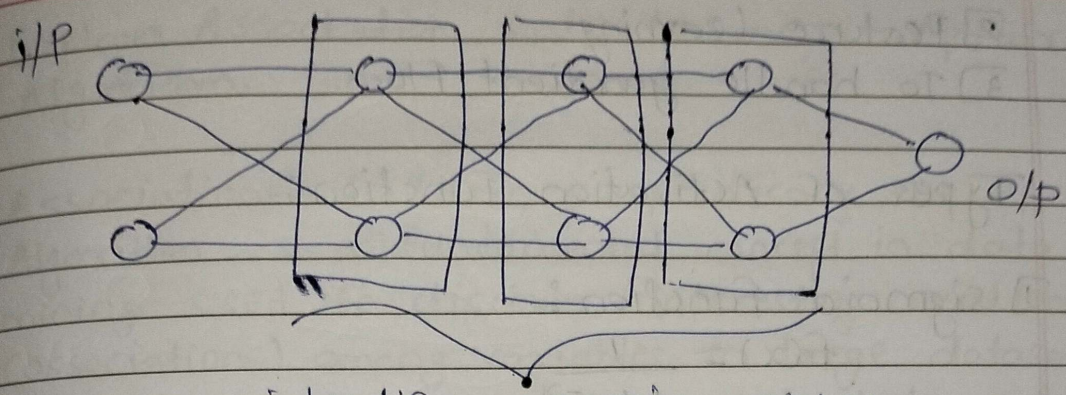
8] Liquid state machine :-



- These neural network nodes that are randomly connected to each other.

9] Resuidal network :

- These is type of deep neural network that allow data to skip a head via a process called as identity mapping, combining output from early layers.



identify mapping skips a head

Components :-
1) convalization
2) Normalization
3) Activation function
4) skip connection.

Advantages :-
1) Solve wanashing Problem
2) improve accuracy
3) scalability.

- Activation function :-
- It is matimatical function
- Applied to the output of neuron or output layer.
- To determine weather neuron should activate or not (By transforming input signal).

$$f(x) = \begin{cases} 1 \text{ if } x \geq 0 \\ 0 \text{ if } x < 0 \end{cases}$$

Why it is important :-
1) To handle non-linearity data

2] Feature Learning
3] To handle gardient Flow.

Types of Activation Function :-

1] sigmoid Function :-

$$f(x) = \frac{1}{1+e^{-x}}$$

- These Function maps input value between 0 or 1
- These Function used for binary classification task.
- In these function vanasing gradient Problem occurs.

2] Relv Function :-

$$f(x) = \max(0, x)$$

- if outputs used as directly Positive returns 1 otherwise return 0.
- Relv Function most of the used in deep Learning models like CNN or RNN
- In that wanasing gradient Problem cannot be occur.

3] SoftMax Function :-

$$f(x_i) = \frac{e^{x_i}}{\Sigma j e^{x_i}}$$

- These Function used in multi-class classification Problem.
- convert vector of value into a Probability distribution.

Que- Explain Association Rule Learning - Apriori Algorithm.

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Association Rule Learning, specifically the Apriori Algorithm is a fundamental concept in data mining used to discover interesting relationships (associations) among variables in large datasets. - It's commonly used in market basket analysis to find patterns, such as which item are frequently bought together.

Key Terms in Association Rule Learning :-

1) Support :- The fraction of transaction in the dataset that contain a specific itemset.

$$\text{Support} = \frac{\text{Number of transactions containing the itemset}}{\text{Total number of transactions.}}$$

2) Confidence :- The likelihood that a specific item B is purchased when A is purchased.

$$\text{confidence} = \frac{\text{support of } (A \cup B)}{\text{support of } A}$$

3) Lift :- measures how much more likely A and B occur together compared to if they were independent.

$$\text{Lift} = \frac{\text{confidence of } (A \rightarrow B)}{\text{support of } B}$$

Steps in the Apriori Algorithm:-

1) set minimum support and confidence Thresholds
2) Generate Frequent Itemsets
3) Generate Association Rule
4) Evaluate Rules using Lift

Example:- Market Basket Analysis

Trasaction ID	Items Bought
T1	Milk, Bread
T2	Milk, Bread, Butter
T3	Bread, Butter
T4	Milk, Butter

1) support calculation:-
   - {Milk} = 3/4 = 0.75
   - {Bread, Butter} = 2/4 = 0.5

2) Frequent Itemsets:-
   - {Milk}, {Bread}, {Butter}
   - {Milk, Bread}, {Bread, Butter}

3) Association Rule:-
   - Rule:- Milk → Bread
   - $\text{Confidence} = \frac{\text{support (milk} \cup \text{Bread)}}{\text{support (Milk)}}$

$$= \frac{0.5}{0.75}$$

$$= 0.66$$

Advantages :-
1) simple and easy to implement
2) Exploits the Apriori principal to reduce computation.

disadvantages :-
1) High computational cost
2) Multiple scans.

Applications :-
1) Market Basket Analysis
2) Fraud Detection
3) Healthcare

Que- Explain model Evaluation and optimization - cross Validation, Grid search and Random search, Hyperparameter Tuning.

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1) Cross-Validation :-
- cross-validation is a technique used to evaluate the performance of a machine learning model by splitting the dataset into subsets.
- It ensures that the model generalizes well to unseen data.

Procedure :-
1) The data is split into k equal parts (Folds)
2) The model is trained on k-1 folds and validated on the remaining fold.
3) This process is repeated k times, with each fold being used as a validation set once.
4) The final performance is averaged across all k iterations.

Advantages :-
1) Reduce the risk of overFitting.
2) Provides a more reliable estimate of model performance compared to a single train test split.

common variants :-
- k-Fold cross-Validation :- splits the data into k folds
- stratified k-Fold cross-validation :- maintains the proportion of classes in each fold.

2] Grid search :-
- Grid search is a brute-force method to find the best hyperparameters for a model by exhaustively searching through a specified set of hyperparameter values.

Procedure :-
1) specify a grid of hyperparameter values to search.
2) For each combination of hyperparameters, train and validate the model using cross-validation.
3) choose the combination that gives the best performance.

Advantages -
- Ensures through exploration of the hyperparameter space.

Disadvantages :-
- computationally expensive
- Not practical for high-dimensional hyper-parameter spaces.

3) Random Search :-
- Random search selects random combinations of hyperparameters to evaluate, rather than exhaustively searching the entire grid.

Procedure :-
- specify ranges for each hyperparameter
- Randomly sample a predefined number of combinations.
- Train and validate the model for each combination using cross-validation.
- choose the combination that yields the best performance.

Advantages :-
1) computationally efficient compared to grid search
2) effective

Disadvantage :-
- might miss the optimal combination if the number of iterations is too low.

4) Hyperparameter Tuning :-
- Hyperparameters are settings the influence how the model learns.
- Tuning these parameters is essential for

improving model performance.

- Approaches to Hyperparameter Tuning :-
  1) Manual search
  2) Grid search
  3) Random search
  4) Bayesian optimization
  5) Automated Hyperparameter Tuning.

Que- Explain Ensemble Learning and Bootstrap Aggregation.

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Ensemble Learning :-

- Ensemble learning is a machine learning technique where multiple models are trained and combined to solve a problem.
- The idea is that by combining the predictions of multiple models, the ensemble can achieve better performance and generalization than any individual model.

key concepts :-

1) Diversity :- The models in the ensemble should mark different errors to ensure their predictions are complementary.

2) Combination Methods :- Predictions from base models are combined using methods like averaging or majority voting.

3) Types of Ensemble Learning :-

- Bagging :- Reduces variance by training models on different subsets of data.
- Boosting :- Focuses on reducing bias by sequentially improving weak models.
- stacking :- Combines predictions of multiple models using a meta-model.

- Bootstrap Aggregation (Bagging) :-
- Bootstrap Aggregation (Bagging) is a specific type of ensemble learning.
- It works by reducing the variance of a model and improving its stability and accuracy.

How Bagging works :-
1) Bootstrap sampling :- Generate multiple datasets by randomly sampling from the original training dataset. Each sample is of the same size as the original dataset.
2) Train multiple models :- Train a separate model on each bootstrap sample independently.
3) Aggregate predictions :- combine the predictions of all models using averaging (for regression) or majority voting (for classification)

Advantages :-
1) Variance Reduction
2) Stability
3) Parallel Training.

Example :- Random Forest

Que- Differentiate between Bagging, Boosting and stacking.

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Feature	Bagging	Boosting	Stacking
Model Training	Models are trained independently in parallel	Models are trained sequentially, where each model corrects the errors of the previous one.	Models are trained independently and a meta-model combines their outputs.
Focus	Reduces variance to prevent overfitting	Reduce bias to improve under-fitting	combines strengths of diverse models for optimal performance.
Data sampling	Uses bootstrap sampling	Works on the same dataset	uses the entire dataset
Combination method	combines outputs by averaging or voting	Combines Predictions using weighted averages	A meta-model learns to optimally combine base model Predictions.
Flexibility	Less Flexible	Focuses on improving a specific type of model	Highly Flexible.
Algorithm	Random Forest, Bagged Trees	AdaBoost, Gradient Boosting, XGBoost, LightGBM	No predefined algorithms

Computational cost	Lower cost	Higher cost	High cost
use case	Best for reducing variance in high-variance models	Best for improving performance in underfitting scenarios	Best for combining diverse models in complex problems.
plications	classification/ regression task	XGBoost for structured data competations.	Ensemble of neural networks, decision trees, and svms for custom tasks.