UNIT-4

* The Immuno System

Immuno Computing: also known Immunological Computation, is a field within NIC that draws inspiration from the vertebrat Immune System's remarkable abilities for info processin.

- The Core idea to develop Computational model the defense mechanisms, learning capabilities alg's that mimic

f organizational structure of the biological Immune Sys to solve Complex Prblms.

- The natural Is served as a highly, parallel, distributed, Adaptive & self organizing model.

Compatational Alg's:

i) Self- Nonself Discrimination

ii) Clonal selection iii) Immune Memory

iv) Negative selection v) Immune Nlw Theory

Applications: Anomaly & Intrusion Detection, optimization, Data mining & clustering, Pattern Recognition.

i) S-N-D: The Is ability to distinguish blw the body's own cell(self) & foreign potentialy harmful entities (non self/antigens).

- Used for anomaly / instrusion detection

i) Clonal selection: when an immune cell recognizes an antigen it is rapidly copied (cloned). The clones are refined through mutation & selection to bind, more effectively to the antigen.

This inspires optimization & ML alg's, such as the clonal selection alg (CSA).

ii) Immune memory: Retains cells for faster future responses.

iv) Negative selection: Destroying immune cells that react to self

v) Immne network Theory: cells & molecules regulating each other in a dynamic N/w.

② Artificial Immuno System (AIS)

- AIS are a type of nature inspired computing that draws on the principles of the biological immune system to solve computational problems.
- They are decentralized, adaptive, & error-tolerant system that use algorithms like negative selection, clonal selection, Immune n/w to perform task anomaly detection, optimization, & pattern recognition.

Working:

- AIS models are designed to replicate the functions of immune cells like B-cells, T-cells & dendritic cells.

- They are based on key immunological concepts such as ability to distinguish b/w self & non self entities.

Algs:

- Negative Selection: An alg that creates detectors for non self patterns, effectively flagging anomalies.
- Clonal Selection: an alg that models the process of immune cell proliferation & selection based on affinity
- Immune Network: An alg that models the interactions between immune cells to maintain a dynamic & self organizing system.
- Self organizing & adaptive: AIS are often self organizing, meaning they don't require manual tuning of system parameters & they can adapt to new data.

Application:

- Computer Security, Anomaly fault detection, optimization, Pattern recognition, Data Analysis

(3) Bone marrow model

- The Bone marrow model in NIC is primarily associated with the Bone marrow stem cell optimization (BMSO) or stem cell alg (SCA), a meta heuristic optimization alg that draws inspiration from the biological function of stem cells & their environment with the bone marrow.

Stem cells which reside in the bone marrow have the remarkable ability to both self-renew & differentiate. This biological process inspires an approach to solving Complex optimization prblms

algs

i) Population Based : like many nI algs (ex: Genetic alg, Swarm optimization).

- BMSO is a Population Based approach.
- each Sell represents a potential soln to the optimization prblm.

ii) Self Renewal & Differentiation as Search.

→ Self-Renewal (Exploitation) : Best or "fittest" Stem cells are ~~re~~ can reproduce & refine their Current Soln. Space.

→ Diffrentation (Exploration) : Stem cells can also differentiate / generate new soln that are Signifi -cantly different from the current ones

iii) Constraints & fitness : The sucess & fate of a Stem Cell are ~~generat~~ governed by certain Constraints & fitness function.

mirroring the biological environment & the body is need for specific Cell types

Applications

- Used as global optimization tool
- Problm solving
- feature selection, Parameter Tuning
- Engineering Optimization

Adv : Simple Implementation, low Computational complexity, & Fast Convergence.

④ Negative Selection Alg

• The NSA is a machine learning technique inspired by the way the vertebrate Immno system distinguishes b/w the body's own cells (self) & foreign invaders (Non self).

• It's primary purpose is Anomaly detection (Identifing the abnormal patterns) in sys where only a Sample of normal behavaior is available taining.

Working

• The NSA is modeled after the negative selection process of T-Lymphocytes (T-cells)

1. T Cell Generation: Immature T-cells are generated randomly in the bone marrow & travel to the thymus.

2. Self-Tolerance (NS): In the ~~system~~ thymus, T-cells are exposed to the body's own proteins (Self-Antigens). Any T-cell that binds too strongly to a "self" protein is eliminated (negatively selected). This prevents auto immune disease.

3. Mutation maturation: only T-cells the survive the selection process - those that do not react to self-are released into the bloodstream. T cells are capable of recognizing & reacting to Non Self (Pathogens)

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NSA Steps

The NSA translates this biological process into a computational method with two main phases.

1) Detector Generation: This phase establishes the ability to recognize Anomalies

2) Anomaly Detection (monitoring phase)

This phase uses the mature detectors to monitor the system in real time.

a) monitor new data when a new data sample (P) enters the system, it is compared against every detector in the set R

b) classification:

- If any detector in R matches the new sample P, then P is flagged as non self (anomaly)
- if no detector in R matches new sample P, then P is flagged as self (normal)

App^{n} :- fault detection, Intrusion Detection Sys, malware/virus detection.

(5) clonal Selection & Affinity maturation

CSAM are key biological concepts from the vertebrate adaptive immune system that inspire a class of NIC alg's.

- used for pattern recognization, optimization.
- These alg's are core part of AIS
- describes how B-lymphocytes (B cell) improve their response to a specific antign (a foreign substance)

• Clonal Selection: When a B cell's receptor successfully binds to an antigen it is selected to rapidly proliferate, creating a large no. of identical copies, or clones.

• Affinity maturation: The newly generated clones undergo a process of accelerated mutation called Somatic hypermutation, in the genes the encode the antibody receptor. Those clone that now have a higher affinity for the antigen are selected to servive & proliferate furthe. low affinity cells die off.

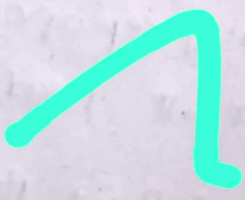
• This process mature's immune response.

• Create effective cells for future encounters.

Keypoints

- Antigen (Ag) The prblm / target pattern
- Antibody (Ab) A candidate soln / Data vector
- Affinity - The fitness / objective function value
- Clonal Selection - Selection / cloning (Reproduction)
- Affinity maturation - Hypermutation
  good soln are mutated less for fine tuning, poor " " more " exploration

Application: optimization, Pattern Recognition, Anamoly detection.



(6) Artificial Immune Networks: (AIN)

- Artificial immune networks (AIN) are computational systems inspired by how the human immune system learns and adapts.
- They are used for pattern recognition, optimisation and anomaly detection by mimicking antibody interactions and memory mechanisms.
- It is based on the immune n/w theory proposed by Niels Jerne in 1974 which says:
  * The immune system can recognise and remember patterns through the interaction of antibodies, not just antigens.

- Working principle of AIN's:

1. Initialization: Generate a population of artificial antibodies
2. Antigen Recognition: present an antigen (problem data) to the network.
3. Affinity Measurement: Evaluate how well each antibody matches the antigen
4. Clonal selection & Mutation: Best antibodies are cloned an slightly mutated to improve th match.
5. Network Interaction: Antibodies interact with one anothe strong connections reinforce learning, u ones are removed.

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6. Memory & Suppression : The best antibodies are stored in memory; redundant ones are suppressed to maintain diversity.

7. Output : The n/w produces an optimized or classified result.

- Applications:

* Data clustering - Grouping similar data automatically
* pattern recognition - Face, voice, or handwriting recognition
* Anomaly Detection - Detecting n/w intrusions or fraud.
* ML - Feature selection and adaptive learning.

- Example:

Prblm : Detect abnormal patterns in n/w traffic (like cyber attacks)

Soln : An AIN is trained with nrml traffic patterns (antibodies) when new data (antigen) arrives, the system checks for a match. If the new pattern differs greatly, it is marked as anomaly or intrusion.

- This mimics how the immune system identifies and reacts to new infections.

(7) From Natural to Artificial Immune Systems:

- The Natural immune system protects the body from harmful pathogens like viruses and bacteria.
- It identifies attacks and remembers foreign invaders using antibodies and immune cells.
- The immune system can learn, adapt and remember past infections. It distinguishes blw self and non-self.
- These intelligent features inspired the development of Artificial immune systems (AIs) in computing.
- AIs is a computational model based on the working principles of the human immune system. It applies immune mechanisms like learning, memory & adaptation to solve computational problems.
- AIs can detect patterns, optimise solutions and identify anomalies in data.
- It works using processes similar to antibody generation, mutation and selection.
- Common AIs alg's include Negative selection, Clonal selection and immune n|w models.
  * Negative selection Alg helps in anomaly or intrusion detection.
  * Clonal selection Alg focuses on learning and improving solutions.
  * Artificial immune n|w's maintain diversity and memory of past patterns.

- AIs mimics immune properties such as diversity, robustness and self organisation. It is used in fields like cyber security, pattern recognition and optimization.
- Ex: AIs can detect computer viruses just like the immune system detects pathogens.
- Hence, moving "from natural to artificial immune systems" means using nature's immune intelligence in technology.

(8) Scope of Artificial Immune Systems:

- Artificial immune systems (AIs) are computational models inspired by the human immune system's ability to learn, adapt and remember.
- The scope of AIs covers a wide range of real-world applications where learning, pattern recognition and anomaly detection are required.
  * In cybersecurity, AIs is used for intrusion detection, virus detection and spam filtering.
  * In ML, it helps in pattern recognition, classification, and feature selection.
  * In optimisation, AIs alg's are used for route optimization, scheduling and resource allocation.
  * In bioinformatics, AIs helps in protein structure prediction, gene analysis & disease detection.