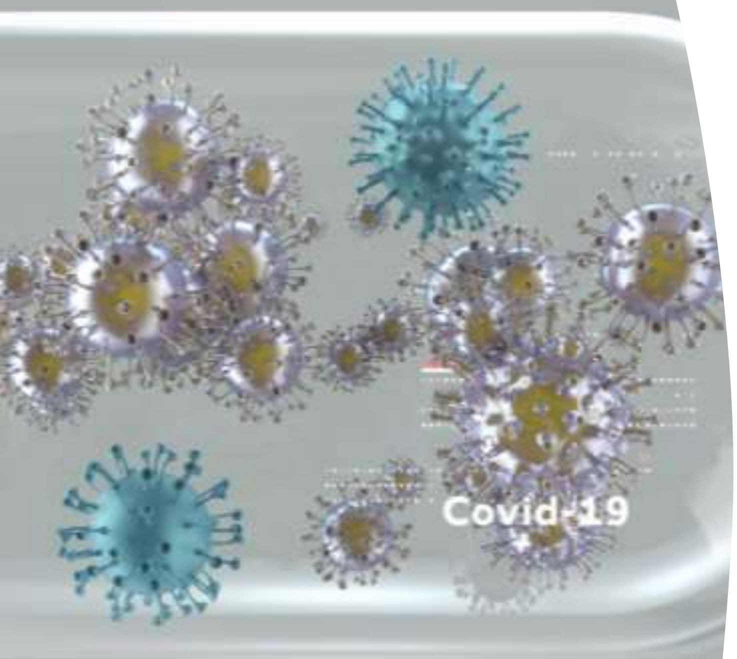
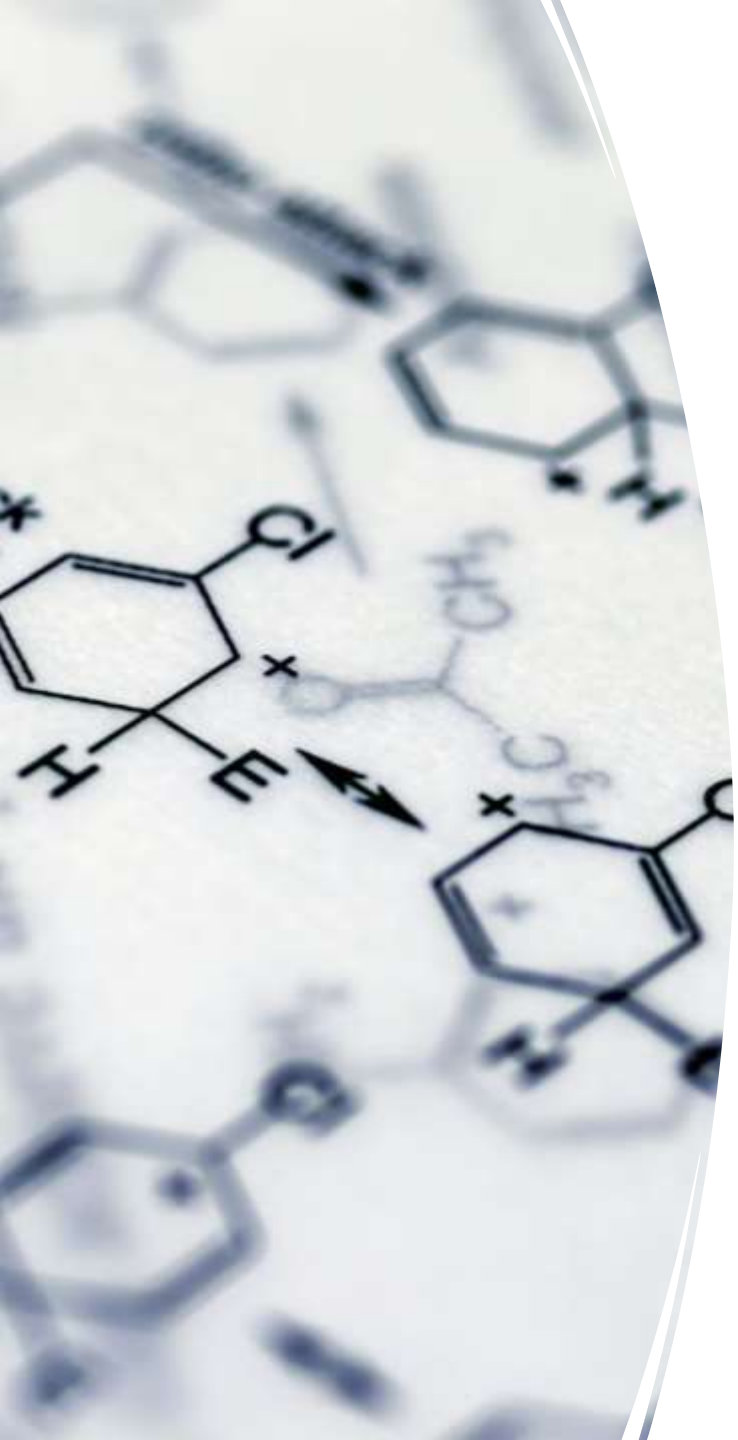


Artificial Immune Systems (AIS)

A Bio-Inspired Computational Approach

Course: Nature inspired Soft Computing
Course Code: 23CS3202



Introduction to AIS

- Artificial Immune Systems (AIS) are computational models inspired by the human immune system.
- Mimic biological immune responses for problem-solving.
- Used in optimization, anomaly detection, and pattern recognition.
- Derived from immunological principles such as self/non-self discrimination, clonal selection, and immune memory.

Biological Inspiration

The human immune system protects against harmful pathogens.

Key immune mechanisms include:

- Antibody recognition and response.
- Clonal selection (adaptive immunity).
- Negative selection (self-tolerance).
- Immune memory (fast response to known threats).

Components of AIS

1. **ANTIGENS (PROBLEM INSTANCES):** INPUT DATA OR OPTIMIZATION PROBLEMS.

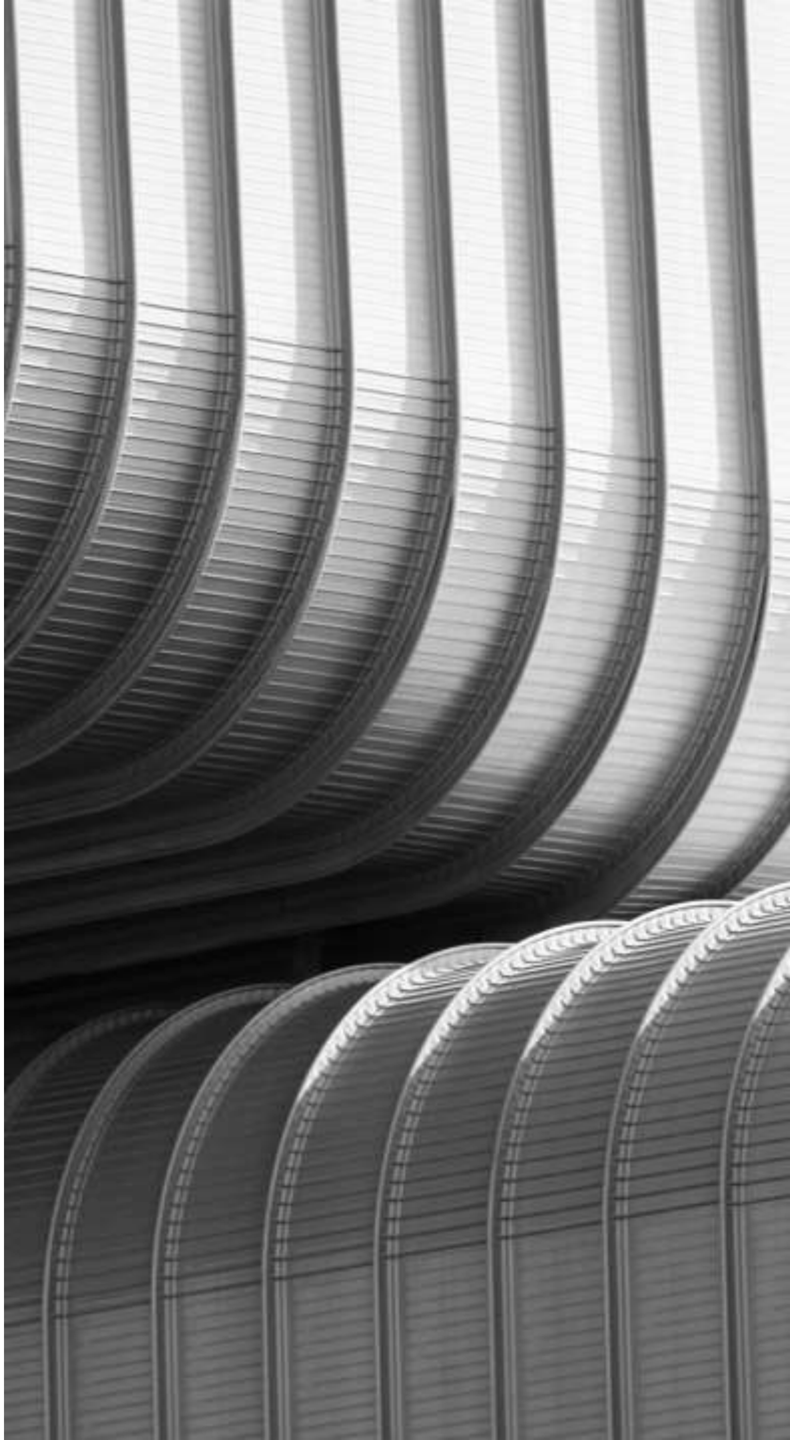
2. **ANTIBODIES (SOLUTIONS):** CANDIDATE SOLUTIONS EVOLVED OVER ITERATIONS.

3. **CLONAL SELECTION:** HIGH-AFFINITY ANTIBODIES ARE CLONED AND IMPROVED.

4. **IMMUNE MEMORY:** BEST SOLUTIONS ARE STORED FOR FUTURE USE.

5. **NEGATIVE SELECTION:** SELF-REACTIVE SOLUTIONS ARE ELIMINATED.

6. **AFFINITY MATURATION:** SOLUTIONS IMPROVE THROUGH MUTATION AND LEARNING.



Types of AIS Algorithms

Clonal Selection Algorithm (CSA): Mimics immune response by generating clones of high-affinity antibodies.

Negative Selection Algorithm (NSA): Used in anomaly detection by distinguishing self from non-self.

Immune Network Algorithm (INA): Models the interaction of antibodies in a dynamic network.

Dendritic Cell Algorithm (DCA): Inspired by dendritic cells, used for security applications.

AIS Algorithm Workflow

1. **Initialize** a random population of antibodies (solutions).

2. **Evaluate Affinity**: Determine how well antibodies recognize antigens (fitness evaluation).

3. **Clonal Expansion**: High-affinity antibodies are cloned.

4. **Affinity Maturation**: Clones undergo small mutations to improve.

5. **Selection**: Best antibodies are retained, others are replaced.

6. **Memory Update**: Best solutions are stored for future use.

7. Repeat until convergence is achieved.

Example: AIS for Anomaly Detection

CONSIDER NETWORK SECURITY MONITORING.

DEFINE 'NORMAL' TRAFFIC AS 'SELF' AND ABNORMAL TRAFFIC AS 'NON-SELF'.

TRAIN THE SYSTEM USING NORMAL DATA (NEGATIVE SELECTION).

DETECT ANOMALIES BY IDENTIFYING MISMATCHES IN INCOMING DATA.

AIS-BASED INTRUSION DETECTION SYSTEMS (IDS) CAN DETECT NOVEL ATTACKS.

Example: AIS for Optimization

Consider function optimization:

Objective: Minimize f(x) = x^2 - 4x + 4.

1. Generate Initial Antibodies (solutions randomly).

2. Evaluate Affinity (compute function values).

3. Clonal Selection & Mutation (mutate better solutions).

4. Retain Best Solutions in memory.

5. Repeat until convergence to an optimal solution.

Advantages and Limitations

Advantages

- Self-learning capability.
- Adaptability to dynamic environments.
- Robustness to noise and uncertainty.
- Can handle high-dimensional problems.

Limitations:

- Computational complexity in large-scale problems.
- Requires fine-tuning of mutation and selection parameters.
- Slower convergence in some optimization tasks.

Applications of AIS

Cybersecurity: Intrusion detection, malware detection.

Optimization: Engineering design, scheduling problems.

Medical Diagnosis: Disease classification, bioinformatics.

Pattern Recognition: Image processing, fraud detection.

Autonomous Systems: Robotics, swarm intelligence.

Conclusion

AIS is a powerful bio-inspired technique for solving complex problems.

Mimics immune responses for learning and adaptation.

Successfully applied in anomaly detection, optimization, and pattern recognition.

Future improvements include hybridization with other AI techniques.