Helwan University | Faculty of Computing & Artificial Intelligence | **MAINSTREAM** Programme
Computational Intelligence (AI430) **Midterm Exam** Wed. 26 March 2025 (Time Allowed: **30 Mins**)
Attempt **ALL Questions** Num. of Pages: **2 Pages** (1 Sheet) – **Closed-book** exam
PLEASE NOTE: Questions 1 to 21 must be answered on the External Answer Sheet.

Question 1: Choose the correct answer *(20 points + 1 bonus question)*

1) __________ is an extreme of exploitation, and __________ is an extreme of exploration. (a) Random Walk / Hill Climbing. (b) Genetic Algorithm / Random Walk. (c) Simulated Annealing / Genetic Algorithm. (d) Random Walk / Simulated Annealing. (e) Hill Climbing / Random Walk.

2) Which parameter does not control the acceptance of a worse solution during the search? (a) The Mutation Rate (p_m) in Genetic Algorithms. (b) The Cooling Schedule in Simulated Annealing. (c) The Revolution Rate (p_{rev}) in the Imperialist Competitive Algorithm. (d) The parameter τ in Extremal Optimization. (e) $1 - HMCR$ "$Harmony\ Memory\ Consideration\ Rate$".

3) For the CI algorithms we've studied, match the principles with their descriptions:

a. Memes b. Stigmergy c. Self-Organised Criticality d. Assimilation	1. Colonies adopting cultural & technological traits of dominant nations. 2. A form of indirect communication mediated by modifications of the environment. 3. A natural process where the least "fit" species is replaced, causing a cascade of local adjustments. 4. Ideas that evolve and improve as they spread within a population.

(a) 4 2 3 1 (b) 2 4 3 1 (c) 3 2 1 4 (d) 4 1 3 2 (e) 1 3 4 2

4) Which of the following algorithms incorporate local search to refine solutions (as opposed to relying only on global search)? (a) Memetic Algorithm. (b) Harmony Search. (c) Genetic Algorithm. (d) Options a & b only. (e) Options a, b, and c.

5) Unlike GAs, which of the following does not use a population-based approach? (a) Extremal Optimization EO. (b) Imperialist Competitive Algorithm ICA. (c) Harmony Search HS. (d) Ant-Colony Optimisation ACO. (e) Memetic Algorithm MA.

6) Which of the following allows the algorithm to explore the neighbourhood of a good solution? (a) Pitch Adjustment Rate (PAR) in HS. (b) Local Search Probability p_{ls} in ME. (c) Both.

7) Simulated annealing balances exploitation and exploration with the temperature parameter. (a) True. (e) False.

8) Simulated annealing only selects neighbour solutions better than the current solution. (a) True. (e) False.

9) If Simulated Annealing is applied to optimise a delivery route with many local minima. How does the algorithm avoid getting trapped? (a) By only accepting better solutions. (b) By using a constant temperature. (c) By restarting from a random solution each iteration. (d) By probabilistically accepting worse solutions using the Metropolis criterion ($P = e^{-\Delta E/T}$).

10) When tuning the parameters of an ICA, increasing which of the following would likely result in faster convergence but a higher risk of getting trapped in local optima? (a) Number of empires N_{imp}. (b) Assimilation coefficient β. (c) Revolution rate p_{rev}. (d) Fitness of an imperialist $C_{imperialist}$.

11) When testing a CA for financial prediction. Why might incorporating a belief space improve performance? (a) It speeds up computations by reducing complexity. (b) It increases randomness, making results more unpredictable. (c) It allows the algorithm to store practical knowledge across generations. (d) It replaces evolutionary operators like selection and mutation. (e) It eliminates the need for a population-based approach.

12) When solving the Travelling Salesman Problem using an MA. Which local search method would be most effective? (a) K-Means Clustering. (b) Gradient Descent. (c) 2-Opt Heuristic. (d) GAs.

13) Which of the following is <u>not</u> a key phase of ICA? (a) Initialisation of countries. (b) Assimilation of colonies. (c) Mutation of empires. (d) Imperialistic competition. (e) Revolution of colonies.

14) If an empire has an imperialist cost of 30 and three colonies with costs 35, 40, and 45, what is its total cost using $\xi = 0.5$? (a) 50. (b) 45. (c) 40. (d) 35. (e) 30

15) Which of these concepts follow a Power-Law Behaviour? (a) The selection bias in τ-EO with a small τ. (b) The sizes of events in systems exhibiting Self-Organised Criticality SOC. (c) The Imperialist Power and Colony Allocation in ICA. (d) All of the above. (e) None of the above.

16) Given a problem where the heuristic information (η) is unreliable; what would be the best adjustment to the Ant-Colony Optimisation (ACO) parameters? (a) Increase both α and β. (b) Reduce the pheromone evaporation rate ρ. (c) Increase the value of α and reduce β. (d) Reduce the number of ants m. (e) Increase the initial pheromone value τ_0.

17) If an ACO-based robotic pathfinding system encounters a dynamic environment where paths change over time, which modification would help? (a) Increase pheromone evaporation. (b) Remove pheromone influence completely. (c) Increase the ant population indefinitely. (d) Stop using heuristic functions. (e) Use a fixed number of iterations only.

18) How does ACO compare to Simulated Annealing (SA) regarding solution search strategy? (a) ACO uses a stochastic global search, whereas SA relies on a cooling schedule. (b) ACO employs pheromone reinforcement, while SA explores solutions using random perturbations. (c) ACO focuses on swarm-based learning, while SA operates with a single solution at a time. (d) SA allows controlled escapes from local optima, whereas ACO relies on pheromone evaporation. (e) All of the above.

19) If the acceptance function in the Cultural Algorithm is too restrictive, what is the most likely outcome? (a) The population becomes highly diverse. (b) The belief space has no influence on evolution. (c) The algorithm generates completely random solutions. (d) The algorithm converges too quickly and may miss the global optimum.

20) In Clustering, the Curse of Dimensionality means that when dimensionality increases, data becomes increasingly dense. Thus, the distance between points, which is critical to clustering, becomes less meaningful. (a) True. (e) False.

21) In k-means, each cluster is represented by an ______, while in the k-medoids (also known as PAM "Partition Around Medoids"), each cluster is represented by an ______. (a) artificial point / artificial point (also). (b) existing point / existing point (also). (c) existing point / artificial point. (d) artificial point / existing point. (e) None of the above (dependent on the data being clustered).

With my best wishes, Dr. Amr S. Ghoneim

Helwan University | Faculty of Computing & Artificial Intelligence | **MAINSTREAM** Programme
Computational Intelligence (AI430) **Midterm Make-Up Exam |** Wed. April 9th, 2025
Closed-book exam | Time Allowed: **40 Mins** | Num. of Pages: **4 Pages** (2 Sheets)

Question 1: Answer 3 of the following 4 questions *(21 points – 7 points each)*

a) Compare population-based and non-population-based metaheuristic algorithms in CI. In your discussion, explain the characteristics and advantages/disadvantages of Genetic Algorithms and Memetic Algorithms versus Extremal Optimisation. Provide examples of problems where each approach might be preferable. *(7 points)*

- **Population-Based Algorithms:**
  - *Genetic Algorithms (GA)* and *Memetic Algorithms (MA)* work with a set of candidate solutions (population).
  - **Advantages:** Diversity promotes exploration; crossover and mutation help combine and refine solutions; parallel search can explore multiple regions of the solution space simultaneously.
  - **Disadvantages:** They may require more computational resources and careful parameter tuning.
- **Non-Population-Based Algorithms:**
  - *Extremal Optimization (EO)* typically works with a single solution that is iteratively improved by replacing the worst-performing components.
  - **Advantages:** Simpler implementation and often lower memory requirements; can be effective for certain types of problems where maintaining a population is unnecessary.
  - **Disadvantages:** They may be more prone to getting stuck in local optima without mechanisms to explore widely.
- **Applicability:**
  - GAs/MAs are suitable for problems where diverse solutions are beneficial (e.g., scheduling, design optimisation). EO might be preferable in environments with limited computational resources or when rapid convergence on a good (if not optimal) solution is acceptable.

b) A Cultural Algorithm (CA) utilises a belief space that stores accumulated knowledge from past generations to guide its evolution process. Consider a scenario where the belief space contains historical data that has proven effective in similar optimisation tasks. *(7 points)*

1. **Explain how the belief space can improve the performance of the CA in a problem like stock market prediction.**
2. **What potential issues might arise if the acceptance function governing updates to the belief space is set too *restrictively*? Provide a brief discussion considering convergence, adaptability, and diversity.**
3. **What happens if the acceptance function is too *permissive*?**

- **Role of Belief Space:**
  - The belief space in CAs holds cultural knowledge, such as trends, constraints, domain-specific insights, or strategies that have been effective in past experiences and that can guide the evolutionary process. **This helps the algorithm to:**
    - Reduce the search space by focusing on promising regions.
    - Improve convergence speed by leveraging prior successful strategies.
    - Enhances the robustness of the algorithm by maintaining useful knowledge across generations.
    - Enhance prediction accuracy by filtering out noisy or irrelevant data.
  - For stock market prediction, this stored historical information can guide the search process by highlighting patterns or indicators that are statistically correlated with market movements (thus, it helps filter noise and emphasise patterns or strategies that have historically led to better predictions).
- **Potential Issues with Restrictive Acceptance Function:**
  - If the acceptance function is too restrictive, it may prevent new (potentially valuable) ideas from being incorporated, leading to premature convergence on suboptimal solutions.
  - Overemphasis on historical knowledge may hinder adaptation to sudden market changes, thereby reducing the algorithm's responsiveness to dynamic environments.
  - **This can lead to:**
    - **Premature Convergence:** The algorithm may overly rely on existing beliefs, ignoring novel information that could lead to better solutions.
    - **Reduced Adaptability:** In dynamic environments like financial markets, too rigid a belief space can hinder the algorithm's ability to adjust to sudden changes or new trends.
    - **Loss of Diversity:** A highly restrictive update rule might cause the algorithm to converge on a narrow set of strategies, reducing the overall diversity and robustness of the search process.
- **If the acceptance function is too permissive;** low-quality solutions enter the belief space, degrading its quality and slowing convergence.

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c) A Simulated Annealing (SA) algorithm is used to optimise a cost function. Consider a situation where the current solution has a cost of 150, and a neighbouring solution has a cost of 165. *(7 points)*

- **Compute the probability of accepting this worse solution when the temperature is 50 using the Metropolis criterion.**
- **Briefly explain how the cooling schedule affects this probability and the algorithm's overall search behaviour.**

Calculation:

The Metropolis acceptance probability is given by:

$$P = \exp\left(-\frac{\Delta E}{T}\right)$$

where $\Delta E = \text{Cost}_{\text{new}} - \text{Cost}_{\text{current}} = 165 - 150 = 15$.
Substituting the values:

$$P = \exp\left(-\frac{15}{50}\right) = \exp(-0.3) \approx 0.7408$$

Therefore, the probability of accepting the worse solution is approximately **74.1%**.

Cooling Schedule Explanation: The cooling schedule determines how the temperature T decreases over iterations. A higher temperature (early in the search) results in a higher acceptance probability for worse solutions, promoting exploration and helping the algorithm escape local optima. As T decreases, the acceptance probability drops, leading the algorithm to become more exploitative—focusing on refining current good solutions. Thus, the cooling schedule directly influences the balance between exploration and exploitation, and improper tuning can either lead to premature convergence or excessive randomness.

d) In an Ant Colony Optimisation (ACO) algorithm applied to a network routing problem, suppose an ant must choose between two paths. The pheromone levels on path A and B are $\tau_A = 2.0$ and $\tau_B = 1.0$, respectively, and the heuristic information (e.g., inverse of distance) for both paths is equal. *(7 points)*

- **If $\alpha = 1$, compute the probability of selecting each path.**
- **Discuss the role of pheromone evaporation in adapting to changes in the network.**

Calculation:

The probability P_i of choosing a path i is given by:

$$P_i = \frac{\tau_i^\alpha}{\sum_j \tau_j^\alpha}$$

For $\alpha = 1$:

$$P_A = \frac{2.0}{2.0 + 1.0} = \frac{2.0}{3.0} \approx 0.6667$$

$$P_B = \frac{1.0}{2.0 + 1.0} = \frac{1.0}{3.0} \approx 0.3333$$

Discussion:

Pheromone evaporation is a critical mechanism in ACO that reduces the influence of past pheromone deposits over time. This decay helps the algorithm "forget" obsolete information, ensuring that outdated or suboptimal paths lose their attractiveness. In dynamic network environments, evaporation allows the system to adapt quickly to changes—such as new traffic conditions or failed links—by gradually reducing the pheromone levels on no longer optimal routes. This enables exploration of alternative paths and prevents the algorithm from prematurely converging on a solution that may no longer be optimal.

With my best wishes, Dr. Amr S. Ghoneim