

Soft Computing

Course Code: CSA301

Unit-wise Assignment Question Bank

Units 1 to 5 · 4, 8, 10 and 12 Mark Questions

Programme	B.Tech. — Computer Science & Engineering
Department	Department of Computer Science & Engineering
School	School of Computing Science & Engineering
Institution	Sharda University, Greater Noida
Faculty	Dr. Gopal Chandra Jana
Total Questions	80

Course page: <https://www.gcjana.in/courses/shardauniversity/2601/soft-computing/>

Post your doubts: [gcjana.in/.../soft-computing/#Post-doubts](https://www.gcjana.in/.../soft-computing/#Post-doubts)

An answer key for all numerical questions is provided in the Appendix.

General Instructions to Students

1. All assignments are to be **handwritten** unless stated otherwise, and submitted as a **single PDF** through the course page.
2. For every numerical question, show **all intermediate steps**. A correct final answer without working carries **at most 40%** of the marks.
3. State all **formulas** before substituting values, and carry units where applicable.
4. Round final numerical answers to **four decimal places** unless the question says otherwise.
5. Where a diagram is asked for, it must be **neatly labelled**; unlabelled diagrams earn no marks.
6. Assignment 1 covers **Units 1 and 2**; Assignment 2 covers **Units 3, 4 and 5**.
7. Copied or identical submissions will be awarded **zero** for all parties involved.
8. Write the **question number and marks** clearly before each answer.

Suggested answer length:

Marks	Expected length	Expected content
4	~half page	definition/statement + one example or one calculation
8	~1 page	explanation + diagram <i>or</i> complete numerical
10	~1.5 pages	full explanation + labelled diagram + numerical
12	2–2.5 pages	derivation + diagram + numerical + discussion

1 Unit 1 — Introduction to Soft Computing

Unit 1: Introduction to Soft Computing

- A. Concept of computing systems; what is Soft Computing? B. “Soft” versus “Hard” computing.
C. Characteristics of Soft Computing and applications of soft computing techniques.

SECTION A — 4 Mark Questions

(Attempt all six)

Q1.

[4 Marks]

Define a *computing system*. State the three essential requirements — precise control action, exactness and certainty — that a conventional (hard) computing system must satisfy, giving one short example of each.

Q2.

[4 Marks]

State *Zadeh’s definition* of Soft Computing and write its guiding principle in full. Identify the four benefits the guiding principle promises.

Q3.

[4 Marks]

Name the four constituent paradigms of Soft Computing. For each, state in one line the type of imperfection it is designed to handle.

Q4.

[4 Marks]

Explain the terms *tractability*, *robustness* and *low solution cost* in the context of Soft Computing, with one example of each.

Q5.

[4 Marks]

List any six characteristics of Soft Computing. Mark which two of them are most responsible for its tolerance of noisy data.

Q6.

[4 Marks]

A fraud-detection dataset contains 999,000 genuine and 1,000 fraudulent transactions.

- (a) Compute the accuracy of a model that always predicts “genuine”.
- (b) Explain in two lines why this makes accuracy an unsuitable measure here, and why the problem is nevertheless well suited to soft computing.

SECTION B — 8 Mark Questions

(Attempt all four)

Q7.

[8 Marks]

Compare Hard Computing and Soft Computing on *any eight* parameters, presenting your answer as a table. Give one concrete application that is best solved by each.

Q8.

[8 Marks]

Explain, with a labelled block diagram, why classical computing fails for the problem of *parallel parking a car*, and how soft computing solves it. Contrast the two approaches on cost, robustness and the need for a mathematical model.

Q9.

[8 Marks]

“Soft Computing is a partnership, not a single technique.” Justify this statement by explaining the complementary roles of Fuzzy Logic, Neural Networks and Genetic Algorithms, and name three hybrid systems formed from them.

Q10.

[8 Marks]

Explain *fault tolerance* and *graceful degradation* in soft computing systems. Sketch a graph of accuracy versus percentage of damaged units for both a hard-computing and a soft-computing system,

and explain the difference in shape.

SECTION C — 10 Mark Questions**(Attempt all three)****Q11.****[10 Marks]**

Describe the *Travelling Salesman Problem* for n cities.

- (a) Derive the number of distinct tours as a function of n and evaluate it for $n = 10$ and $n = 20$.
- (b) If a computer evaluates 10^9 tours per second, compute the time required for $n = 20$ in years.
- (c) Explain why a Genetic Algorithm is preferred, and state precisely what is given up in exchange.

Q12.**[10 Marks]**

Explain *Machine Learning*, *Fuzzy Logic* and *Evolutionary Computation* as members of the soft computing family. For each, state (i) the source of inspiration, (ii) the class of problem it addresses, and (iii) one real deployed application. Conclude with a labelled “soft computing umbrella” diagram.

Q13.**[10 Marks]**

Discuss any *five* societal applications of soft computing techniques (one each from healthcare, transport, consumer appliances, power systems and finance). For each, name the technique used and justify in two lines why hard computing is unsuitable.

SECTION D — 12 Mark Questions**(Attempt all three)****Q14.****[12 Marks]**

- (a) Explain the concept of a computing system, its control action, and the notions of exactness and certainty. (4)
- (b) Identify five real-world problems that cannot be solved by conventional computing, and classify each by the reason for failure (no model, vague data, or intractability). (4)
- (c) For each of the five problems, name the most appropriate soft computing technique and justify the choice. (4)

Q15.**[12 Marks]**

- (a) State and explain all the characteristics of Soft Computing. (6)
- (b) State four limitations of Soft Computing and, for each, suggest one practical mitigation. (4)
- (c) Give two domains where soft computing must *not* be used, with reasons. (2)

Q16.**[12 Marks]**

Trace the historical development of Soft Computing from 1943 to 1995.

- (a) Prepare an annotated timeline naming at least six milestones with year and contributor. (6)
- (b) Explain the significance of Zadeh’s 1965 and 1994 contributions. (3)
- (c) Explain how the Sendai Subway project (1987) changed industrial acceptance of fuzzy systems. (3)

2 Unit 2 — Fuzzy Logic

Unit 2: Fuzzy Logic

A. Introduction to fuzzy logic; fuzzy sets and membership functions. **B.** Operations on fuzzy sets; fuzzy relations, rules, propositions, implications and inferences. **C.** Defuzzification techniques; fuzzy logic controller design; societal applications.

SECTION A — 4 Mark Questions

(Attempt all six)

Q1.

[4 Marks]

Define a *fuzzy set* and its *membership function*. State two differences between a crisp set and a fuzzy set, using the characteristic function in your answer.

Q2.

[4 Marks]

Define *support*, *core*, *height*, *normality* and α -*cut* of a fuzzy set. Illustrate all five on a single labelled trapezoidal membership function.

Q3.

[4 Marks]

A triangular membership function for *Warm* is defined by the triple $\{10, 20, 30\}$. Compute $\mu_{\text{Warm}}(x)$ for $x = 15, 20, 24$ and 35 , showing the formula used in each case.

Q4.

[4 Marks]

Given $\mu_A(x) = 0.6$ and $\mu_B(x) = 0.35$ at a point x , compute $\mu_{A \cup B}$, $\mu_{A \cap B}$, $\mu_{\bar{A}}$, and the value of “*very A*”. State the operator used for each.

Q5.

[4 Marks]

State the two classical laws of set theory that *fail* for fuzzy sets. Demonstrate the failure numerically at a point where $\mu_A = 0.4$.

Q6.

[4 Marks]

Distinguish between *fuzzy logic* and *probability theory* on four points, giving one example statement of each kind.

SECTION B — 8 Mark Questions

(Attempt all four)

Q7.

[8 Marks]

Two fuzzy sets on $X = \{1, 2, 3, 4, 5\}$ are

$$A = \frac{0.3}{1} + \frac{0.7}{2} + \frac{1.0}{3} + \frac{0.6}{4} + \frac{0.2}{5}, \quad B = \frac{0.8}{1} + \frac{0.4}{2} + \frac{0.5}{3} + \frac{0.9}{4} + \frac{0.6}{5}.$$

Compute (a) $A \cup B$, (b) $A \cap B$, (c) $\bar{A}$, (d) *very A*, (e) *more-or-less A*, and (f) the 0.5-level α -cut of A . Verify De Morgan's law $\overline{A \cup B} = \bar{A} \cap \bar{B}$ at $x = 1$.

Q8.

[8 Marks]

Define a *fuzzy relation* and the *max-min composition*. Given

$$R = \begin{pmatrix} 0.2 & 0.7 \\ 0.9 & 0.4 \end{pmatrix}, \quad S = \begin{pmatrix} 0.6 & 0.3 \\ 0.5 & 1.0 \end{pmatrix},$$

compute $R \circ S$, showing the calculation for every element.

Q9.

[8 Marks]

Explain *linguistic variables*, *linguistic hedges* and *fuzzy propositions*. Show mathematically how the hedges “very” and “more or less” modify a membership function, and sketch all three curves on one axis.

Q10.

[8 Marks]

Explain the *compositional rule of inference* (generalised modus ponens). Contrast it with classical modus ponens, and state what happens when the observed fact exactly equals the rule antecedent.

SECTION C — 10 Mark Questions

(Attempt all three)

Q11.

[10 Marks]

- (a) Explain the four stages of the fuzzy inference pipeline with a labelled block diagram. (5)
- (b) An aggregated output fuzzy set is given on the universe $y \in \{10, 20, 30, 40, 50\}$ with memberships $\mu = \{0.1, 0.5, 0.9, 0.4, 0.2\}$ respectively. Compute the defuzzified output by the *centre of gravity* method. (5)

Q12.

[10 Marks]

Describe any *four* defuzzification techniques with their formulas. Apply the centroid and the mean-of-maximum methods to the data of the previous question and compare the two results, explaining why they differ.

Q13.

[10 Marks]

Draw and explain the block diagram of a *Fuzzy Logic Controller*, naming all functional blocks. Design a fuzzy controller for a room air-conditioner: define the linguistic variables, sketch the membership functions, and write at least five IF–THEN rules.

SECTION D — 12 Mark Questions

(Attempt all three)

Q14.

[12 Marks]

- (a) State all the standard operations on fuzzy sets with their formulas. (4)
- (b) List the properties that fuzzy sets retain from classical set theory and those they lose, with justification. (4)
- (c) Using A and B from Question 7 above, verify the associative and distributive laws at $x = 3$. (4)

Q15.

[12 Marks]

- (a) Explain fuzzy IF–THEN rules and the Mamdani and Larsen implication operators. (4)
- (b) A fuzzy controller has the rules
 R1: IF temperature is *Cool* THEN fan is *Slow*;
 R2: IF temperature is *Pleasant* THEN fan is *Medium*.
 At $T = 16^\circ\text{C}$ the memberships are $\mu_{\text{Cool}} = 0.3$ and $\mu_{\text{Pleasant}} = 0.4$. Trace the complete inference through fuzzification, implication, aggregation and defuzzification. (6)
- (c) State two advantages of a fuzzy controller over a conventional PID controller. (2)

Q16.

[12 Marks]

- (a) Discuss any six real-life societal applications of fuzzy logic, naming the input and output variables in each. (6)
- (b) Explain in detail how a fuzzy washing machine works, from sensing to actuation. (4)
- (c) State two limitations of fuzzy systems that motivate the study of neuro-fuzzy systems. (2)

3 Unit 3 — Fuzzy Inference System

Unit 3: Fuzzy Inference System

A. Fuzzy Inference Systems; Mamdani and Sugeno fuzzy models. **B.** Tsukamoto fuzzy model; input-space partitioning and fuzzy modelling. **C.** Neuro-fuzzy modelling: ANFIS architecture, hybrid learning, ANFIS and RBFN.

SECTION A — 4 Mark Questions

(Attempt all six)

Q1.

[4 Marks]

Define a *Fuzzy Inference System*. Name its five functional blocks and state the function of each in one line.

Q2.

[4 Marks]

State the general rule form of the *Mamdani* and the *Sugeno* models. Identify precisely what differs between them.

Q3.

[4 Marks]

Distinguish between a *zero-order* and a *first-order* Sugeno model, giving the consequent equation of each.

Q4.

[4 Marks]

Why must the consequent membership function of a *Tsukamoto* model be monotonic? Explain using the inverse function C_i^{-1} .

Q5.

[4 Marks]

A fuzzy system has 4 input variables, each partitioned by 5 membership functions. Compute the number of rules required by a complete grid partition, and comment on the result.

Q6.

[4 Marks]

Name the two parameter sets of an ANFIS and state which layer each belongs to and which optimisation method updates each.

SECTION B — 8 Mark Questions

(Attempt all four)

Q7.

[8 Marks]

Compare the Mamdani, Sugeno and Tsukamoto fuzzy models on *any six* parameters in tabular form, and state a situation in which each is the preferred choice.

Q8.

[8 Marks]

A first-order Sugeno system has two rules:

R1: IF x is A_1 THEN $z_1 = 2x + 3$; R2: IF x is A_2 THEN $z_2 = x + 1$.

At $x = 5$ the firing strengths are $w_1 = 0.4$ and $w_2 = 0.6$. Compute the normalised weights and the crisp output, showing every step. Repeat for a three-rule system with $w = (0.2, 0.5, 0.3)$ and $f = (10, 20, 30)$.

Q9.

[8 Marks]

Explain the three *input-space partitioning* strategies — grid, tree and scatter — with a sketch of each. State the advantage, the disadvantage and a suitable application of every strategy.

Q10.

[8 Marks]

Explain the *hybrid learning algorithm* of ANFIS. Present a table showing which parameters are fixed and which are updated in the forward and backward passes, and justify why this is faster than pure gradient descent.

SECTION C — 10 Mark Questions

(Attempt all three)

Q11.**[10 Marks]**

- (a) Explain the working of the Mamdani fuzzy model with a labelled diagram showing clipping and aggregation. (5)
- (b) The aggregated output of a Mamdani system on the universe $z \in \{1, 2, 3, 4, 5\}$ has memberships 0.2, 0.5, 0.8, 0.6, 0.3 respectively.
Compute the crisp output by the centroid method. (5)

Q12.**[10 Marks]**

Draw the five-layer *ANFIS architecture* for a two-input, two-rule first-order Sugeno system. Write the node output equation of every layer, and clearly mark which nodes are adaptive and which are fixed.

Q13.**[10 Marks]**

Explain *structure identification* and *parameter identification* in fuzzy modelling. Discuss the curse of dimensionality with numerical illustration for $n = 2, 3, 5$ inputs and $m = 5$ membership functions, and state two strategies to control the rule explosion.

SECTION D — 12 Mark Questions**(Attempt all three)****Q14.****[12 Marks]**

- (a) Derive the output expression of a two-rule first-order ANFIS and prove that it is *linear* in the consequent parameters. (6)
- (b) Explain how this property is exploited by the least-squares estimation step, writing the normal-equation solution. (4)
- (c) State two limitations of ANFIS. (2)

Q15.**[12 Marks]**

- (a) Explain the Tsukamoto fuzzy model with a labelled diagram. (4)
- (b) Two Tsukamoto rules fire with strengths $w_1 = 0.7$ and $w_2 = 0.3$, and the inverted monotonic consequents give $z_1 = 8$ and $z_2 = 4$. Compute the final crisp output. (4)
- (c) Compare the computational cost of Mamdani, Sugeno and Tsukamoto models and justify why Sugeno underlies ANFIS. (4)

Q16.**[12 Marks]**

- (a) Explain the motivation for neuro-fuzzy modelling by listing the strengths and weaknesses of fuzzy systems and neural networks. (4)
- (b) Describe the functional equivalence between ANFIS and a Radial Basis Function Network, stating the conditions under which it holds. (5)
- (c) Explain two practical benefits obtained from this equivalence. (3)

4 Unit 4 — Swarm and Evolutionary Algorithms

Unit 4: Swarm and Evolutionary Algorithms

A. Concept of genetics and evolution and its application to probabilistic search. **B.** Basic GA framework and architectures; GA operators; single-objective optimisation. **C.** Swarm optimisation: Ant Colony Optimization, Particle Swarm Optimization.

SECTION A — 4 Mark Questions

(Attempt all six)

Q1. [4 Marks]

Map any six terms of natural genetics (individual, chromosome, gene, allele, fitness, generation) to their counterparts in a Genetic Algorithm.

Q2. [4 Marks]

Define *exploration* and *exploitation*. State which GA operator provides each, and describe what happens when either dominates.

Q3. [4 Marks]

A 5-bit binary string 10110 encodes a variable x in the range $[0, 10]$. Decode it using the standard decoding formula, showing all steps.

Q4. [4 Marks]

Perform single-point crossover at position $k = 2$ on the parents 11010 and 00101. Give the two offspring and their decoded integer values.

Q5. [4 Marks]

Write the transition-probability formula of Ant Colony Optimization and define every symbol. State the role of the parameters α and β .

Q6. [4 Marks]

Write the velocity-update equation of Particle Swarm Optimization and name its three components, explaining the role of each.

SECTION B — 8 Mark Questions

(Attempt all four)

Q7. [8 Marks]

Draw and explain the flowchart of a basic Genetic Algorithm. State three possible stopping criteria and give typical values for population size, crossover rate and mutation rate.

Q8. [8 Marks]

A population of four chromosomes has x -values 5, 10, 15 and 20, with fitness $f(x) = x^2$.

- Compute the fitness of each and the total fitness.
- Compute the roulette-wheel selection probability of each.
- Compute the expected number of copies of each in a mating pool of size 4.
- Comment on which chromosome is likely to disappear.

Q9. [8 Marks]

Explain *Ant Colony Optimization* with the concepts of pheromone deposition, evaporation and stigmergy. Write the pheromone-update equation and explain the purpose of the evaporation term.

Q10. [8 Marks]

Compare Genetic Algorithms, Ant Colony Optimization and Particle Swarm Optimization on *any six* parameters in tabular form, and state the class of problem best suited to each.

SECTION C — 10 Mark Questions**(Attempt all three)****Q11.****[10 Marks]**

- (a) Explain the four GA operators — encoding, selection, crossover and mutation — with one example of each. (6)
- (b) Explain any three selection schemes and state one advantage of each over roulette-wheel selection. (4)

Q12.**[10 Marks]**

An ant at node i may move to nodes A , B or C . The pheromone and heuristic values are:

Edge	τ	η
A	3.0	0.50
B	2.0	1.00
C	4.0	0.25

With $\alpha = 1$ and $\beta = 2$, compute the transition probability of each edge, showing the numerator and denominator explicitly. Identify the most likely next node and explain why it is not the edge with the highest pheromone.

Q13.**[10 Marks]**

A particle in a one-dimensional PSO has $x = 3.0$, $v = 1.5$, personal best $p = 5.0$ and global best $g = 8.0$. With $w = 0.6$, $c_1 = c_2 = 2.0$, $r_1 = 0.4$ and $r_2 = 0.5$:

- (a) Compute the three components of the velocity update separately. (4)
- (b) Compute the new velocity and the new position. (3)
- (c) Interpret the result and explain why velocity clamping is often applied. (3)

SECTION D — 12 Mark Questions**(Attempt all three)****Q14.****[12 Marks]**

- (a) Explain the concepts of genetics and evolution and show how they are translated into a probabilistic search technique. (4)
- (b) Classify search techniques into calculus-based, enumerative and guided-random, and explain where GAs fit. (4)
- (c) Explain why gradient-based methods fail on multi-modal landscapes, with a sketch. (4)

Q15.**[12 Marks]**

Consider maximising $f(x) = x^2$ for $x \in [0, 31]$ using 5-bit encoding, with the initial population 01101, 11000, 01000, 10011.

- (a) Decode each string and compute its fitness and selection probability. (4)
- (b) Perform single-point crossover on the two fittest strings at $k = 4$ and compute the fitness of the offspring. (4)
- (c) Apply a bit-flip mutation to one offspring and comment on whether the population has improved after one generation. (4)

Q16.**[12 Marks]**

- (a) Explain the principles of swarm intelligence: decentralisation, local interaction, self-organisation and stigmergy. (4)
- (b) Explain the complete ACO algorithm for the Travelling Salesman Problem, including tour construction and pheromone update. (5)
- (c) Discuss any three real applications of swarm optimisation. (3)

5 Unit 5 — Multi-objective Optimization Problem Solving

Unit 5: Multi-objective Optimization Problem Solving

A. Concept of multi-objective optimisation problems (MOOPs) and issues in solving them. **B.** Multi-Objective Evolutionary Algorithms: non-Pareto and Pareto-based approaches; applications of MOEAs.

SECTION A — 4 Mark Questions

(Attempt all six)

Q1.

[4 Marks]

Give the formal mathematical statement of a multi-objective optimisation problem, defining the objective vector, the constraints and the feasible region.

Q2.

[4 Marks]

State the condition for *Pareto dominance* under minimisation. Determine whether (4, 7) dominates (4, 9), and whether (3, 8) dominates (5, 6), justifying each answer.

Q3.

[4 Marks]

Distinguish between the *Pareto-optimal set* and the *Pareto front*, stating clearly which space each occupies.

Q4.

[4 Marks]

Name the two goals that every MOEA must achieve simultaneously, and explain what a solution set looks like when each goal is met but the other is not.

Q5.

[4 Marks]

Why does the weighted-sum method fail to find solutions on a non-convex portion of the Pareto front? Illustrate with a sketch.

Q6.

[4 Marks]

State the three pillars of the NSGA-II algorithm and name the operator used to break ties within a front.

SECTION B — 8 Mark Questions

(Attempt all four)

Q7.

[8 Marks]

Seven solutions are evaluated on two objectives, both to be *minimised*:

Solution	A	B	C	D	E	F	G
f_1	3	5	7	6	9	4	8
f_2	9	6	4	8	2	10	7

Identify all dominated solutions, list the Pareto-optimal set, and sketch the Pareto front on a labelled f_1 - f_2 plot.

Q8.

[8 Marks]

Using the four non-dominated solutions from the previous question, apply the weighted-sum method with weight vectors (0.5, 0.5), (0.7, 0.3) and (0.3, 0.7). Tabulate all values, identify the winner for each weighting, and state the conclusion you draw about the method.

Q9.

[8 Marks]

Explain the ε -constraint method with its mathematical formulation and a sketch. State one advantage it has over the weighted-sum method and one disadvantage it shares with it.

Q10.

[8 Marks]

Explain the *VEGA* algorithm with a block diagram. State its principal weakness and explain why Pareto-based approaches were developed to overcome it.

SECTION C — 10 Mark Questions**(Attempt all three)****Q11.****[10 Marks]**

- (a) Explain the *fast non-dominated sorting* procedure, defining n_p and S_p . (5)
- (b) Apply it to the seven solutions of Question 7 above and list the members of every front $\mathcal{F}_1, \mathcal{F}_2, \dots$ (5)

Q12.**[10 Marks]**

- (a) Define the *crowding distance* and write its formula, explaining the purpose of the range normalisation. (4)
- (b) For the front consisting of (3, 9), (5, 6), (7, 4) and (9, 2), compute the crowding distance of every solution and rank them for truncation. (6)

Q13.**[10 Marks]**

Explain the complete NSGA-II generation cycle with a labelled diagram, covering the combination of parent and offspring populations, front-wise filling, the splitting front and the crowded-comparison operator. State how elitism is guaranteed.

SECTION D — 12 Mark Questions**(Attempt all three)****Q14.****[12 Marks]**

- (a) Explain the concept of multi-objective optimisation and illustrate the mapping between decision space and objective space with a labelled diagram. (5)
- (b) Discuss any five issues that make MOOPs harder than single-objective problems. (5)
- (c) Explain why a population-based evolutionary approach is naturally suited to MOOPs. (2)

Q15.**[12 Marks]**

- (a) Classify the approaches for solving MOOPs into non-Pareto and Pareto-based, naming at least three algorithms in each class. (4)
- (b) Compare NSGA-II, SPEA2 and MOEA/D on ranking, diversity mechanism, elitism and suitability. (5)
- (c) Explain the hypervolume indicator and state why it is preferred over generational distance alone. (3)

Q16.**[12 Marks]**

- (a) Discuss any four engineering or scientific applications of MOEAs, naming the conflicting objectives in each. (4)
- (b) Explain the portfolio-optimisation problem as a MOOP and describe the efficient frontier. (4)
- (c) Briefly describe the wider family of nature-inspired optimisers — GA+PSO hybrids, memetic algorithms, differential evolution, artificial bee colony, firefly and cuckoo search — and state their relation to multi-objective optimisation. (4)

Appendix — Answer Key for Numerical Questions

For instructor use. Final answers only — students must show complete working to earn full marks.

Unit 1

- **Q6.** Accuracy = $999000/1000000 = 99.9\%$, yet it detects *zero* fraud; accuracy is meaningless under extreme class imbalance (use precision/recall/F1).
- **Q13.** Tours = $(n-1)!/2$. $n = 10 : 181\,440$; $n = 20 : \approx 6.08 \times 10^{16}$.
Time at $10^9/\text{s} = 6.08 \times 10^7 \text{ s} \approx 1.93 \text{ years}$.

Unit 2

- **Q3.** $\mu(15) = \frac{15-10}{10} = 0.5$; $\mu(20) = 1.0$; $\mu(24) = \frac{30-24}{10} = 0.6$; $\mu(35) = 0$.
- **Q4.** $\cup = 0.60$, $\cap = 0.35$, $\bar{A} = 0.40$, very $A = 0.6^2 = 0.36$.
- **Q5.** At $\mu_A = 0.4$: $A \cup \bar{A} = \max(0.4, 0.6) = 0.6 \neq 1$; $A \cap \bar{A} = \min(0.4, 0.6) = 0.4 \neq 0$.
- **Q7.** $A \cup B = (0.8, 0.7, 1.0, 0.9, 0.6)$; $A \cap B = (0.3, 0.4, 0.5, 0.6, 0.2)$;
 $\bar{A} = (0.7, 0.3, 0.0, 0.4, 0.8)$; $A^2 = (0.09, 0.49, 1.00, 0.36, 0.04)$;
 $A^{0.5} = (0.548, 0.837, 1.000, 0.775, 0.447)$; $\alpha_{0.5}(A) = \{2, 3, 4\}$.
De Morgan at $x = 1$: $1 - 0.8 = 0.2$ and $\min(0.7, 0.2) = 0.2 \checkmark$
- **Q8.** $R \circ S = \begin{pmatrix} 0.5 & 0.7 \\ 0.6 & 0.4 \end{pmatrix}$.
e.g. $(1, 1) = \max\{\min(0.2, 0.6), \min(0.7, 0.5)\} = \max\{0.2, 0.5\} = 0.5$.
- **Q11(b).** $\sum y\mu = 64.0$, $\sum \mu = 2.1$, $y^* = 64.0/2.1 = 30.4762$.
- **Q12.** Centroid = **30.4762**; MoM = **30** (single peak at $\mu = 0.9$).

Unit 3

- **Q5.** $m^n = 5^4 = 625$ rules — rule explosion.
- **Q8.** $z_1 = 2(5) + 3 = 13$, $z_2 = 5 + 1 = 6$; $\bar{w}_1 = 0.4$, $\bar{w}_2 = 0.6$;
 $z^* = 0.4(13) + 0.6(6) = 5.2 + 3.6 = 8.8$.
Three-rule case: $\frac{0.2(10)+0.5(20)+0.3(30)}{1.0} = \frac{2+10+9}{1} = 21.0$.
- **Q11(b).** $\sum z\mu = 0.2 + 1.0 + 2.4 + 2.4 + 1.5 = 7.5$; $\sum \mu = 2.4$;
 $z^* = 7.5/2.4 = 3.125$.
- **Q13.** $n = 2 : 25$; $n = 3 : 125$; $n = 5 : 3125$ rules.
- **Q15(b).** $z^* = \frac{0.7(8)+0.3(4)}{1.0} = \frac{5.6+1.2}{1.0} = 6.8$.

Unit 4

- **Q3.** $d = (10110)_2 = 22$; $x = 0 + \frac{22}{31}(10) = 7.0968$.
- **Q4.** Children 11101 = **29** and 00010 = **2** (parents were 26 and 5).
- **Q8.** $f = (25, 100, 225, 400)$, $\sum f = 750$.
 $p = (0.0333, 0.1333, 0.3000, 0.5333)$;
expected copies = $(0.133, 0.533, 1.200, 2.133)$. $x = 5$ is likely to vanish.
- **Q12.** Numerators: $A : 3.0(0.5)^2 = 0.75$; $B : 2.0(1.0)^2 = 2.00$; $C : 4.0(0.25)^2 = 0.25$; $\Sigma = 3.00$.
 $P(A) = 0.2500$, $P(B) = 0.6667$, $P(C) = 0.0833$. B wins despite lower pheromone because $\beta = 2$ magnifies its visibility.

- **Q13.** inertia = $0.6(1.5) = 0.90$; cognitive = $2(0.4)(5 - 3) = 1.60$; social = $2(0.5)(8 - 3) = 5.00$; $v^{\text{new}} = \mathbf{7.50}$, $x^{\text{new}} = 3.0 + 7.5 = \mathbf{10.50}$ (overshoots g — hence clamping).
- **Q15.** $x = (13, 24, 8, 19)$, $f = (169, 576, 64, 361)$, $\sum f = 1170$;
 $p = (0.1444, 0.4923, 0.0547, 0.3085)$.
 Crossover of 01101×11000 at $k = 4$ gives $01100 = 12$ ($f = 144$) and $11001 = 25$ ($f = \mathbf{625}$) — the population has improved (best was 576).

Unit 5

- **Q2.** $(4, 7)$ dominates $(4, 9)$: equal in f_1 , strictly better in $f_2 \Rightarrow \mathbf{yes}$. $(3, 8)$ vs $(5, 6)$: better in f_1 , worse in $f_2 \Rightarrow \mathbf{non-dominated}$.
- **Q7.** Dominated: **D, F, G**. Pareto-optimal set = **{A,B,C,E}**, i.e. $(3, 9), (5, 6), (7, 4), (9, 2)$.
- **Q8.** $(0.5, 0.5)$: $A=6.0, B=5.5, C=5.5, E=5.5$ (three-way tie).
 $(0.7, 0.3)$: $A=\mathbf{4.8}, B=5.3, C=6.1, E=6.9 \Rightarrow A$ wins.
 $(0.3, 0.7)$: $A=7.2, B=5.7, C=4.9, E=\mathbf{4.1} \Rightarrow E$ wins.
 Conclusion: each weight vector yields only *one* point, so the front must be swept.
- **Q11(b).** $\mathcal{F}_1 = \{\mathbf{A,B,C,E}\}$; $\mathcal{F}_2 = \{\mathbf{D,F,G}\}$.
- **Q12(b).** Ranges $f_1 : 9 - 3 = 6, f_2 : 9 - 2 = 7$.
 $(3, 9)$ and $(9, 2)$ are boundaries $\Rightarrow d = \infty$.
 $(5, 6)$: $\frac{7-3}{6} + \frac{9-4}{7} = 0.6667 + 0.7143 = \mathbf{1.3810}$.
 $(7, 4)$: $\frac{9-5}{6} + \frac{6-2}{7} = 0.6667 + 0.5714 = \mathbf{1.2381}$.
 Truncation order: boundaries first, then $(5, 6)$, then $(7, 4)$.

End of Assignment Question Bank — Soft Computing (CSA301)

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