National University of Computer and Emerging Sciences
Lahore Campus

Simulation and Modeling (CS 4096)
Comprehensive Boids Question Bank

Name:	____________________	**Roll No:**	____________________
Date:	December 18, 2025	**Score:**	____________________

Part A: Conceptual & History (Easy)

1. Origins
Who introduced the Boids algorithm, and in what year was it famously presented at SIGGRAPH?
Solution: Craig Reynolds, 1987.

2. Local vs. Global
True or False: In a standard Boids simulation, a central "leader" agent tells all other birds where to fly to maintain the flock formation.
Solution: False. Boids is an emergent behavior algorithm; complex global behavior emerges from local rules followed by individual agents without a leader.

3. Rule Identification
Match the rule to its definition:

- A. Separation — 1. Steer towards the average heading of neighbors.
- B. Alignment — 2. Steer towards the average position of neighbors.
- C. Cohesion — 3. Steer to avoid crowding local flockmates.

Solution: A-3, B-1, C-2.

Part B: Vector Fundamentals (Medium)

4. Normalization
A boid's velocity vector is $V = (3, 4)$. Calculate the normalized direction vector $\hat{u}$.
Solution:
Magnitude $||V|| = \sqrt{3^2 + 4^2} = \sqrt{9 + 16} = \sqrt{25} = 5$.
$\hat{u} = V/||V|| = (3/5, 4/5) = (\mathbf{0.6}, \mathbf{0.8})$.

5. Distance Calculation
Boid A is at $(10, 10)$ and Boid B is at $(13, 14)$. What is the distance between them?
Solution:
$\Delta x = 13 - 10 = 3$. $\Delta y = 14 - 10 = 4$.
Distance $d = \sqrt{3^2 + 4^2} = \mathbf{5}$.

Part C: Core Logic Scenarios (Medium)

6. 1D Alignment
Boid X is moving right $(+5)$. It sees two neighbors: Y $(+10)$ and Z (-2). Calculate the alignment vector (average velocity of neighbors).
Solution:
$V_{avg} = (V_Y + V_Z)/2 = (10 + (-2))/2 = 8/2 = \mathbf{4}$.

7. 2D Cohesion (Center of Mass)
A Boid P is at $(2, 2)$. It sees neighbors at $(4, 4)$ and $(6, 2)$. Calculate the steering force for Cohesion: $V_{coh} = (P_{avg} - P_{pos})/10$.
Solution:
$P_{avg} = \frac{(4,4)+(6,2)}{2} = \frac{(10,6)}{2} = (5, 3)$.
$V_{coh} = ((5, 3) - (2, 2))/10 = (3, 1)/10 = (\mathbf{0.3}, \mathbf{0.1})$.

Part D: Advanced Logic (Hard)

8. 3D Cohesion

A Boid P is located at position $(1, 2, 3)$ in 3D space. It perceives three neighbors:

$$A : (2, 2, 2), \quad B : (0, 4, 3), \quad C : (1, 0, 4)$$

Calculate the Cohesion Vector (V_{coh}) for Boid P.

$$V_{coh} = \frac{P_{avg} - P_{pos}}{100}$$

Solution:
$P_{avg} = \frac{(2+0+1, 2+4+0, 2+3+4)}{3} = \frac{(3,6,9)}{3} = (1, 2, 3)$.
$V_{coh} = ((1, 2, 3) - (1, 2, 3))/100 = (\mathbf{0}, \mathbf{0}, \mathbf{0})$.
(The boid is already at the center of the flock).

9. Separation with Inverse Weighting

Boid X is at $(0, 0)$. Neighbors: $Y : (2, 0)$ and $Z : (0, 1)$. Calculate separation force:

$$V_{sep} = \sum \frac{P_X - P_{neighbor}}{||P_X - P_{neighbor}||^2}$$

Solution:
For Y: $D = (-2, 0)$, $dist^2 = 4$. Force = $(-0.5, 0)$.
For Z: $D = (0, -1)$, $dist^2 = 1$. Force = $(0, -1)$.
Total $V_{sep} = (-0.5, 0) + (0, -1) = (\mathbf{-0.5}, \mathbf{-1})$.

10. Field of View (FOV)

Boid M at $(0, 0)$ faces North $(0, 1)$. FOV is 90° (45° half-angle). Neighbor N is at $(2, 2)$. Is N visible?
Hint: $\cos(45°) \approx 0.707$.

Solution:
Vector to N: $(2, 2)$. Normalized: $(0.707, 0.707)$.
Dot Product with Facing $(0, 1)$: $0(0.707) + 1(0.707) = 0.707$.
Since $0.707 \geq \cos(45°)$, **Yes, it is visible (on the edge)**.

Part E: Optimization & Algorithmic Complexity (Hard)

11. Naive vs. Optimized

In a naive implementation, every boid checks every other boid to find neighbors. a. What is the Big-O time complexity for one frame of simulation with N boids? b. Name a data structure used to optimize this to near $O(N)$.

Solution:
a. $O(N^2)$. (Each of N boids checks N-1 others).
b. **Spatial Hashing / Quadtree / Octree / Grid Partitioning**.

12. Neighbor Lookup

If the world size is 1000×1000 and the grid cell size is 50×50, how many cells does the grid contain?
Solution:
$1000/50 = 20$ cells per row.
$20 \times 20 = \mathbf{400}$ cells total.

Part F: Expert Challenge Questions

13. Speed Limiting and Clamping
Current Velocity $V_{old} = (3, 0)$. Steering Force $F = (0, 4)$. Max Speed = 4. Calculate the final velocity.

Solution:
Tentative $V = (3, 0) + (0, 4) = (3, 4)$.
Magnitude $= 5$.
Since $5 > 4$, scale by $4/5 = 0.8$.
Final $V = (3 \times 0.8, 4 \times 0.8) = (\mathbf{2.4}, \mathbf{3.2})$.

14. Toroidal World (Wrap-Around)
World Width = 100. Boid moves from $x = 98$ with velocity $v_x = 5$. Calculate its new x-position.

Solution:
Raw Position $= 98 + 5 = 103$.
Wrapped Position $= 103 \mod 100 = \mathbf{3}$.

15. Blind Spot Calculation
A predator P approaches a boid B from directly behind. Boid B has velocity $(1, 0)$ (moving East). Predator P is at $(-5, 0)$. The Boid's total Field of View is $270°$ (blind spot is $90°$ behind it). Can Boid B see Predator P?

Solution:
1. Boid Facing: $\vec{F} = (1, 0)$.
2. Vector to Predator: $\vec{V}_{BP} = (-5, 0) - (0, 0) = (-5, 0)$. Normalized $\hat{u} = (-1, 0)$.
3. Dot Product: $(1)(-1) + (0)(0) = -1$.
4. Angle: $\cos^{-1}(-1) = 180°$.
5. Blind Spot Logic: The boid sees $135°$ left and right. $180° > 135°$.
Answer: No, the predator is in the exact center of the blind spot.

16. Weighted Prioritization
A boid has two conflicting urges: 1. Avoid Obstacle (Vector $V_{obs} = (1, 0)$, Weight = 3.0) 2. Cohesion (Vector $V_{coh} = (0, 1)$, Weight = 1.0) Calculate the final steering vector.

Solution:
$V_{final} = (3.0 \times 1, 3.0 \times 0) + (1.0 \times 0, 1.0 \times 1)$
$V_{final} = (3, 0) + (0, 1) = (\mathbf{3}, \mathbf{1})$.

17. Delta Time Integration
Why do we multiply velocity by Δt (time step) when updating position ($P_{new} = P_{old} + V \cdot \Delta t$)?

Solution:
To make the simulation **frame-rate independent**. Without Δt, boids would move faster on faster computers (higher FPS) and slower on slower computers.