National University of Computer and Emerging Sciences
Lahore Campus

Simulation and Modeling
(CS 4096)

Date: November 27, 2025 **Course Instructor(s):** Dr. Mirza Mubasher Baig

Quiz

Total Time (Hrs): 0.5	**Total Weight:** 2	**Total Questions:** 4

Roll No: ______________________ **Section:** ______________________

Student Signature: ____

Instructions: Answer in the space provided. Attach extra sheets if really needed. In Case of any missing values state your assumptions clearly.

Boids is the classic agent-based model of flocking behavior introduced by Craig Reynolds. A Boid is an agent in a flock that moves in 2D or 3D space according to three core rules:

1. **Separation** – avoid crowding neighbors (short-range repulsion).
2. **Alignment** – match velocity with nearby flockmates.
3. **Cohesion** – move toward the average position of nearby flockmates.

At each time step, the Boid updates its velocity as a weighted combination of these rules and then updates its position:

$$V_{new} = V_{old} + W_s V_{sep} + W_a V_{align} + W_c V_{cohesion}$$

$$P_{new} = P_{old} + V_{new}$$

where W_s, W_a, and W_c are weights for separation, alignment, and cohesion.

1. Three Boids are moving in a 1D space. Their velocities at the current time step are:
i) Boid A: $V_A = 2$ **ii) Boid B:** $V_B = 4$ **iii) Boid C:** $V_C = 6$

Consider only alignment behavior and assume Boid A sees both B and C as neighbors. The alignment velocity update for Boid A is:

$$V_{align} = (\text{average neighbor velocity} - V_A)/8$$

(Note: Denominator assumed to be 8 based on standard Reynolds algorithm)

a. Compute the alignment contribution V_{align} for Boid A.

Solution:
Average neighbor velocity $= (V_B + V_C)/2 = (4 + 6)/2 = 5$.
$V_{align} = (5 - 2)/8 = 3/8 = \mathbf{0.375}$.

b. What is its new velocity of Boid A after applying alignment only?

Solution:
Assuming no weight or weight = 1 for this context:
$V_{new} = V_A + V_{align} = 2 + 0.375 = \mathbf{2.375}$.

2. Now assume that Boids are in 2D space. A Boid P is at position $(2, 3)$ and it sees three neighbors at positions: Q: $(4, 5)$, R: $(5, 2)$ and S: $(3, 6)$ respectively. The cohesion vector is computed as:

$$V_{cohesion} = (P_{avg} - \text{Position})/2$$

where P_{avg} is the average position of neighbors. Compute the cohesion vector $V_{cohesion}$ of the Boid at position P.

Solution:
$P_{avg} = \frac{Q+R+S}{3} = \left(\frac{4+5+3}{3}, \frac{5+2+6}{3}\right) = \left(\frac{12}{3}, \frac{13}{3}\right) = (4, 4.33)$.
$V_{cohesion} = \frac{(4,13/3)-(2,3)}{2} = \frac{(2,13/3-9/3)}{2} = \frac{(2,4/3)}{2} = (\mathbf{1}, \mathbf{2/3})$ or $(\mathbf{1}, \mathbf{0.67})$.

3. A Boid X is at $(1, 1)$ and has two close neighbors Y: $(2, 1)$ and Z: $(1, 2)$. Separation vectors for Boids are computed as the negative difference from neighbors:

$$V_{sep} = \sum_{\text{neighbors}} (P_X - P_{neighbor})$$

Compute V_{sep} for Boid X.

Solution:
$P_X - P_Y = (1, 1) - (2, 1) = (-1, 0)$.
$P_X - P_Z = (1, 1) - (1, 2) = (0, -1)$.
$V_{sep} = (-1, 0) + (0, -1) = (\mathbf{-1}, \mathbf{-1})$.

4. A Boid M is at $(0, 0)$ with velocity $V_M = (1, 1)$. Following are the three velocity update components computed using the neighbors of M:

$$V_{sep} = (-2, 0), \quad V_{align} = (0, 1), \quad V_{cohesion} = (1, 2)$$

Compute the new position of M using the following weights for the three components:

$$W_s = 0.5, \quad W_a = 1, \quad \text{and} \quad W_c = 0.25$$

Solution:
Calculate weighted components:
$W_s V_{sep} = 0.5(-2, 0) = (-1, 0)$.
$W_a V_{align} = 1(0, 1) = (0, 1)$.
$W_c V_{cohesion} = 0.25(1, 2) = (0.25, 0.5)$.

Calculate New Velocity (V_{new}):
$V_{new} = V_{old} + \text{components} = (1, 1) + (-1, 0) + (0, 1) + (0.25, 0.5)$.
$V_{new} = (1 - 1 + 0 + 0.25, \quad 1 + 0 + 1 + 0.5) = (0.25, 2.5)$.

Calculate New Position (P_{new}):
$P_{new} = P_{old} + V_{new} = (0, 0) + (0.25, 2.5) = (\mathbf{0.25}, \mathbf{2.5})$.