PJV Project: Real-Time Bacterial Survival Simulation

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This project implements a multithreaded, real-time simulation of bacterial behavior in a Petri dish environment. The simulation emphasizes concurrent thread management, GUI visualization, and user-configurable parameters to simulate bacterial movement, reproduction, and competition for resources.

Environment Setup

Grid

- Represents a square Petri dish containing bacteria and nutrients. All bacterial requests are processed here.

- **Grid Size**: Up to 20x20 cells. Each cell can contain:

    - **0–100 nutrient units**

    - **Bacterium ID** (if occupied)

    - NULL (if empty)

- **(Optional) Toxic Cells**: User-defined cells that drain bacterial energy and block nutrient spawning.

Nutrient Regeneration

- **Spawning**: Random number of nutrients spawn at random intervals (default: 5–15 ticks).

- **Adjustability**:

    - Spawn interval is user-adjustable.

    - Spawn logic avoids occupied cells to prevent overcrowding.

Bacterial Behavior

Movement

- **Energy Costs**:

    - **-2 energy units** when moving to a new cell.

    - **-1 energy unit** when staying idle.

- **Pathfinding**:

    - Random movement by default.

    - *Optional*: Advanced nutrient-seeking (prioritizes cells with the highest nutrients in a radius).

Feeding

- **Consumption**: When a bacterium enters a cell with nutrients, it consumes all available units.

- **Energy Gain**: Each nutrient unit provides **1 energy point**.

- **Absorption:** If two bacteria meet on a single cell. The bacteria with higher number of energy will absorb the other bacteria and get its energy.

Reproduction

- **Conditions**:

  o Energy reaches a user-defined threshold (adjustable via GUI).

  o Requires at least one adjacent empty cell.

- **Mechanics**:

  o Splits into multiple bacteria (one remains in the original cell; others occupy adjacent empty cells, adjustable via GUI).

  o Reproduction consumes energy equal to the threshold.

  o New bacteria spawn with predefined energy levels (user-configurable).

Death

- **Triggers**:

  o Starvation: Dies if no nutrients are consumed within a user-defined number of ticks.

  o Energy depletion: Dies if energy reaches 0.

- **Legacy**: Replaced by nutrients equal to its maximum energy level.

GUI Implementation

Grid Visualization

- Visualizes the grid's current state using color-coded cells:

  o **Bacteria**: Red (intensity scales with energy, red to purple).

  o **Nutrients**: Green (opacity scales with nutrient count).

Statistics Panel

- Displays real-time metrics:

  o Total bacteria count

  o Nutrient cell count

  o Average bacterial energy

  o Occupied/empty cell ratio

  o Average nutrient count per cell

User Controls

- **Adjustable Parameters**:
    - Sliders:
        - Nutrients per spawn (1–10)
        - Reproduction energy threshold (1–10)
        - Initial bacterial energy (1–10)
        - Starvation death ticks (1–20)
        - Number of reproduced bacteria (1–8)
    - Buttons:
        - Pause/resume simulation
        - Reset grid
- **Interactive Grid (Optional)**:
    - **Right-click**:
        - Add nutrients to empty cells or add nutrients to a nutrient cell.
        - Increase bacterial energy.
    - **Left-click**:
        - Remove nutrients.
        - Decrease bacterial energy (only in paused mode).

Default Settings

If no user adjustments are made, the simulation uses base parameters:

- Grid size: 10x10
- Nutrient spawn interval: 10 ticks
- Reproduction threshold: 5 energy units
- Starvation death ticks: 10

Startup options

- All parameters can be set when starting the project.

All parameters are not final and can be adjusted while working on the project.

Optional means that the feature might not be implemented when the project is submitted.