Emergency Department (ED) Simulation System Documentation

1. Introduction

This document describes the simulation system of an Emergency Department (ED) with four main areas: Arrival, Waiting, Treatment, and Exit. The system processes patients based on severity, prioritizing critical cases and managing the flow from arrival to treatment to exit. It includes essential components, such as patient prioritization, room status updates, and performance metrics.

2. Simulation Environment and Areas

1. **Arrival Area**
   - **Process**: Patients check in, capturing their arrival time, severity level, and estimated treatment duration.
   - **Transition Logic**:
     - If a slot is available in the treatment room, the patient moves directly to treatment.
     - If not, the patient enters the waiting area.
2. **Waiting Area**
   - **Priority Assignment**:
     - Each patient is assigned a priority based on severity and waiting time. Severity levels are:
       - **Critical**: High priority
       - **Urgent**: Medium priority
       - **Non-Urgent**: Low priority
     - Waiting increases priority after specific cycles (e.g., after 2 cycles, a non-urgent case becomes medium priority, and so forth).
   - **Signals**:
     - Receives signals from the treatment area indicating available slots and dispatches patients based on priority.
3. **Treatment Area**
   - **Process**: Patients receive care for a duration based on their severity.

- **Exit Criteria**: Once the treatment duration is completed, the patient exits, and a signal is sent to the waiting area to indicate an available slot.

4. **Exit Area**
   - **Data Collection**: Information on total treatment time, waiting time, arrival date, and other relevant data is recorded for reporting and analysis.

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3. Class Structure

1. **Patient Class**
   - **Attributes**:
     - `patient_id`: Unique identifier for the patient.
     - `arrival_time`: Time the patient checked in.
     - `severity`: Severity level of the patient (critical, urgent, non-urgent).
     - `priority_level`: Priority level based on severity and wait time.
     - `waiting_time`: Total waiting time in cycles.
     - `treatment_duration`: Time allocated for treatment based on severity.
   - **Methods**:
     - `update_priority()`: Adjusts priority based on waiting time.
     - `get_info()`: Returns patient's information for processing and reporting.

2. **Bed Class**
   - **Attributes**:
     - `bed_id`: Unique identifier for the bed.
     - `is_occupied`: Status indicator (occupied or vacant).
     - `occupying_patient_id`: Identifier of the patient occupying the bed.
   - **Methods**:
     - `assign_patient(patient_id)`: Assigns a patient to the bed.
     - `release_bed()`: Frees the bed when a patient exits.

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4. Formulas

1. **Patient Density Update**
   - Equation:

$$\rho_{t+1}(x, y) = \rho_t(x, y) + \Delta t(-\nabla \cdot (\rho_t u_t))$$

- **Description**: Updates patient density in each zone over time, considering both current density and flow.

2. **Velocity Field Update**
   - Equation:

$$u_{t+1}(x, y) = u_t(x, y) + \Delta t \left(-u_t \cdot \nabla u_t - \frac{1}{\rho_t} \nabla p + \frac{\mu}{\rho_t} \nabla^2 u_t + \frac{f}{\rho_t} \right)$$

   - **Components**:
     - **Inertial Term**: Represents patient movement.
     - **Pressure Gradient**: Reflects "pressure" due to patient accumulation.
     - **Viscous Term**: Frictional force due to delays and obstacles.
     - **External Force (f)**: Models policies or external influences on flow.

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5. Reports

- **Arrival Area**:
  - **Reports**: Patient count, average arrival time, and severity distribution.
- **Waiting Area**:
  - **Reports**: Queue size, average waiting time by severity, average priority increase rate.
- **Treatment Area**:
  - **Reports**: Utilization rate (occupied vs. vacant beds), average treatment time, discharge rate by severity.
- **Exit Area**:
  - **Reports**: Summary statistics including total ED time per patient, breakdown by waiting and treatment times, and exit counts per severity level.
- **Patient Class**:
  - **Reports**: Patient journey log (arrival, priority adjustments, entry to treatment, exit).
- **Bed Class**:
  - **Reports**: Bed utilization stats, average occupancy duration, and release frequency.

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6. Simulation Cycle and Flow

1. **Arrival**:
   - New patients enter and check in at the arrival area.

2. **Waiting and Priority Adjustment**:
   - Patients are prioritized in the waiting area, and adjustments occur based on severity and wait cycles.

3. **Treatment**:
   - Patients with the highest priority are admitted to the treatment area.

4. **Exit**:
   - Upon treatment completion, patients exit, and data is collected in the exit area.