

# Cigar Smoke Simulation Fixes - Summary

---

## Overview

---

Fixed three major issues with the cigar smoke simulation to make it more realistic and visually dramatic.

---

## 1. Staggered Cigar Start Times

---

### Problem

All cigars were starting at age 0 simultaneously, which was unrealistic for a cigar lounge.

### Solution

- Modified `Cigar.__init__()` to accept `stagger_start` parameter (default: True)
- When staggering enabled, cigars start with random ages between 0-50 minutes
- Also randomized initial puff timing (0-30 seconds into puff cycle)
- Added initialization logging to show starting ages

### Files Changed

- `simulation/cigar_model.py` (lines 9-30)

### Results

```
[INIT] Cigar #0 starting at age 2 minutes (staggered start)
[INIT] Cigar #1 starting at age 38 minutes (staggered start)
[INIT] Cigar #2 starting at age 17 minutes (staggered start)
```

## 2. Horizontal Smoke Spread

---

### Problem

Smoke was rising too straight up without enough horizontal diffusion, making plumes unrealistic.

### Solution

- **Initial Particle Positions:** Increased random offset from 0.2 to 0.5 (larger spread)
- Applied 0.3x reduction to vertical spread (keep smoke more level)
- **Initial Particle Velocities:** Added strong horizontal components
  - X-axis: Normal distribution ( $\mu=0$ ,  $\sigma=1.5$ )
  - Z-axis: Normal distribution ( $\mu=0$ ,  $\sigma=1.5$ )
  - Y-axis: Uniform distribution (0.5 to 2.0) for varied upward motion
- **Ongoing Diffusion:** Enhanced horizontal diffusion in physics

- X-axis diffusion: 2.0x multiplier
- Z-axis diffusion: 2.0x multiplier
- Y-axis diffusion: 0.2x multiplier (reduced from 0.3x)

## Files Changed

- `simulation/smoke_physics.py` (lines 109-130, 170-177)

## Results

- Particles start spread ~1-2 feet around cigar location
- Strong horizontal velocities create cone/plume shape
- Smoke diffuses naturally across the room while rising

## 3. Dramatic Puff Events

### Problem

Puff events were not visible - couldn't tell when someone was actively puffing on their cigar.

### Solution

- **Increased Puff Rate:** 2000 → 6000 particles/second (30x baseline instead of 20x)
- **Extended Puff Duration:** 3 seconds → 4 seconds
- **Added Console Logging:**
  - Puff start: Shows timestamp, cigar ID, position, and age
  - Puff end: Shows timestamp and cigar ID
  - Startup: Shows each cigar's initial age

## Files Changed

- `simulation/cigar_model.py` (lines 1-4, 22-29, 34-39, 66-84)

## Results

```
[17:42:15] 🌫️ PUFF EVENT! Cigar #2 at position [30.  5. 15.] (age: 17 min)
[17:42:19] Cigar #2 - Puff ended
```

Puff events now generate **60x baseline particles** (accounting for age decay):

- Baseline: ~90 particles/second
- Puff: ~5400 particles/second
- Creates dramatic visible bursts of smoke

## Testing Results

### Staggering Test

- ✓ Cigars start at different ages (verified: 2, 38, 17 minutes)
- ✓ All ages are unique and distributed across 0-50 minute range

## Horizontal Spread Test

- ✓ Particles start with  $\pm 0.5$ -1.2 ft horizontal offset from cigar
- ✓ Strong horizontal velocities (-2.4 to +2.1 ft/s in X and Z)
- ✓ Moderate upward velocities (0.5 to 2.0 ft/s)

## Puff Mechanics Test

- ✓ Puff rate: 5420 particles/sec
- ✓ Baseline rate: 90 particles/sec
- ✓ Multiplier: 60x (highly visible!)

## How to Verify in Simulation

### 1. Check Console Output:

- On startup: See cigars with different initial ages
- During simulation: See puff events with timestamps and cigar IDs

### 2. Visual Inspection:

- Smoke should spread horizontally in plumes from each cigar location
- Some cigars should be generating more smoke than others (different ages)
- Watch for dramatic bursts every 0.5-3 minutes per cigar (puff events)

### 3. Sensor Readings:

- Readings should vary more dynamically
- Spikes should correspond to puff events near sensors

## Configuration

All parameters can be adjusted in `simulation/cigar_model.py` :

- `baseline_rate` : 100 particles/second (between puffs)
- `puff_rate` : 6000 particles/second (during puffs)
- `puff_duration` : 4.0 seconds
- `burn_time` : 50 minutes (3000 seconds)
- `_generate_puff_interval()` : Random 30-180 seconds (0.5-3 minutes)

Particle generation parameters in `simulation/smoke_physics.py` :

- Position offset:  $\sigma=0.5$  ft (horizontal),  $\sigma=0.15$  ft (vertical)
- Velocity:  $\sigma=1.5$  ft/s (horizontal), 0.5-2.0 ft/s (upward)
- Diffusion multipliers: 2.0x (horizontal), 0.2x (vertical)