

3D Visualization Coordinate System Fix

Issue

The 3D visualization was displaying the room with incorrect orientation, making it appear "on its side" with axes mislabeled or confusingly positioned.

Coordinate System Definition

Standard Coordinate Mapping

The simulation uses the following coordinate system consistently throughout:

- X-axis: Width (0-30 ft) - horizontal left/right
- Y-axis: Height (0-20 ft) - VERTICAL up/down
- Z-axis: Length (0-75 ft) - horizontal front/back (depth)

Room Corners (for reference)

Front face (Z=0):

- Front-left-bottom: (0, 0, 0)
- Front-right-bottom: (30, 0, 0)
- Front-left-top: (0, 20, 0)
- Front-right-top: (30, 20, 0)

Back face (Z=75):

- Back-left-bottom: (0, 0, 75)
- Back-right-bottom: (30, 0, 75)
- Back-left-top: (0, 20, 75)
- Back-right-top: (30, 20, 75)

Changes Made to `visualization/renderer_3d.py`

1. Camera View Angle Adjustment

Before:

```
self.camera_elevation = 30.0
self.camera_azimuth = -45.0
```

After:

```
self.camera_elevation = 20.0    # Look slightly down from above
self.camera_azimuth = -60.0    # View from front-left corner
```

Reason: The new angles provide a better perspective showing the room upright with Y-axis clearly vertical.

2. Enhanced Axis Setup

Added comprehensive documentation and improved axis labels:

- Clear dimension indicators in labels
- Room dimensions shown in title ($30 \times 20 \times 75$ ft)
- Added aspect ratio correction using `set_box_aspect()`
- Detailed comments explaining coordinate system

3. Room Drawing Corrections

Floor and Ceiling:

- Floor rectangle at $Y=0$ (bottom)
- Ceiling rectangle at $Y=20$ (top)
- Both drawn in XZ plane (horizontal planes)

Floor Grid:

- Grid lines properly drawn on $Y=0$ plane
- Lines parallel to Z -axis at X intervals
- Lines parallel to X -axis at Z intervals

4. Fan Positioning Fix

Critical Fix: Fan circle orientation was incorrect.

Before: Fan drawn in YZ plane (vertical circle)

```
circle_x = np.full(segments + 1, pos[0]) # Constant X
circle_y = pos[1] + radius * np.cos(angles) # Y varies
circle_z = pos[2] + radius * np.sin(angles) # Z varies
```

After: Fan drawn in XY plane at back wall ($Z=75$)

```
circle_x = pos[0] + radius * np.cos(angles) # X varies
circle_y = pos[1] + radius * np.sin(angles) # Y varies
circle_z = np.full(segments + 1, pos[2]) # Constant Z=75
```

Reason: Fan is on back wall ($Z=75$), so circle should be perpendicular to Z -axis, lying in the XY plane.

5. Sensor Visualization Enhancement

- Increased marker size ($100 \rightarrow 120$)
- Increased edge thickness ($1.0 \rightarrow 1.5$)
- Enhanced connecting line visibility
- Added documentation explaining sensor positions

6. Particle Rendering

- Added `depthshade=True` for better 3D perception
- Comprehensive documentation of particle coordinate mapping
- Verified correct axis usage ($X=\text{width}$, $Y=\text{height}$, $Z=\text{depth}$)

Element Positions Verification

Fan

```
Position: [5.0, 15.0, 75.0]
- 5 ft from left wall (X)
- 15 ft up from floor (Y)
- On back wall (Z=75)
```

Sensors

```
Each pair has:
- X: Spread across width based on pair ID
- Y: low_height (e.g., 5 ft) and high_height (e.g., 15 ft)
- Z: Distance from back wall toward front
```

Smoke Particles

```
Positions: (N, 3) numpy array
- Column 0: X (width, 0-30 ft)
- Column 1: Y (height, 0-20 ft) - vertical movement
- Column 2: Z (depth, 0-75 ft)
```

Physics Integration

The coordinate system matches the physics simulation:

Boundary Conditions (`smoke_physics.py`)

```
# X boundaries (width)
mask = self.particles_positions[:, 0] < 0 or > ROOM_WIDTH

# Y boundaries (height - vertical)
mask = self.particles_positions[:, 1] < 0 or > ROOM_HEIGHT

# Z boundaries (length - depth)
mask = self.particles_positions[:, 2] < 0 or > ROOM_LENGTH
```

Smoke Behavior

- **Horizontal spread:** X and Z components (with diffusion multipliers)
- **Vertical rise:** Y component (with height-dependent buoyancy)
- **Stratification:** Height zones defined by Y values (4-8 ft hover zone, etc.)

Expected Visual Result

After these fixes, the 3D view should display:

1. **Upright Room:** Y-axis clearly vertical (floor at bottom, ceiling at top)
2. **Correct Dimensions:** 30×20×75 ft visible in title and axis ranges
3. **Fan on Back Wall:** Circular fan at correct position (X=5, Y=15, Z=75)
4. **Sensors Positioned Correctly:** Vertical pairs spread across room

5. **Smoke Particles:** Rising vertically and spreading horizontally

6. **Natural View Angle:** Looking down from front-left corner

Testing

To verify the fixes:

1. Launch the application: `python main.py`

2. Start simulation with 4 cigars

3. Verify:

- Room appears upright with Y-axis vertical
- Fan circle is visible on back wall (not floating in space)
- Smoke particles rise vertically and spread horizontally
- Sensor pairs show vertical alignment
- All dimensions match 30×20×75 ft

Files Modified

- `visualization/renderer_3d.py` - Complete coordinate system documentation and fixes

Files Verified (Already Correct)

- `utils/constants.py` - Room dimensions correct (30×20×75)
- `simulation/smoke_physics.py` - Boundary conditions use correct axes
- `simulation/sensor.py` - Sensor positioning uses correct coordinates
- `simulation/fan.py` - Fan position correct [5, 15, 75]