User Guide - Cigar Lounge Smoke Simulation Tool

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Getting Started

Installation

1. **Install Python 3.8+** (if not already installed)
   ```bash
   python3 --version  # Check your Python version
   ```

2. **Install Dependencies**
   ```bash
   pip install -r requirements.txt
   ```

3. **Run the Application**
   ```bash
   python main.py
   ```

First Time Setup

When you first launch the application:
1. You'll see a 3D view of the empty room on the left
2. Control panels are below the 3D view
3. Data displays and graphs are on the right side

User Interface Overview

Main Window Layout

The application window is divided into two main sections:

Left Panel: 3D View and Controls

- **3D Visualization**: Shows the room, smoke particles, sensors, and fan
- Use mouse to rotate view (click and drag)

- Use mouse wheel to zoom in/out
- **Control Tabs**:
- **Simulation Tab**: Start/pause/reset, smoker count, simulation speed
- **Sensors Tab**: Add/remove sensor pairs and configure positions
- **Fan Control Tab**: Switch between manual/auto mode, set fan speed

Right Panel: Data and Analysis

- **Data Tabs**:
- **Sensor Readings**: Real-time PPM and clarity values for all sensors
- **Graphs**: Time-series plots of PPM, clarity, and fan speed
- **Statistics**: Summary statistics and export options

Running a Simulation

Basic Workflow

Step 1: Set Number of Smokers

1. Go to **Simulation** tab (bottom left)
2. Adjust “Number of Smokers” spinner (0-48)
3. Default is 24 smokers

Step 2: Add Sensor Pairs (Optional but Recommended)

1. Go to **Sensors** tab
2. Set sensor configuration:
   - **Distance from Fan**: How far from the fan (in feet)
   - **Low Sensor Height**: Height of low sensor from floor
   - **High Sensor Height**: Height of high sensor from floor
3. Click “Add Sensor Pair”
4. Repeat to add up to 4 pairs

Recommended Sensor Configurations:
- **Near-Fan Pair**: 10ft from fan, Low:3ft, High:12ft
- **Mid-Room Pair**: 35ft from fan, Low:3ft, High:12ft
- **Far Pair**: 60ft from fan, Low:3ft, High:12ft

Step 3: Configure Fan Control

1. Go to **Fan Control** tab
2. Choose mode:
   - **Manual**: You control fan speed with slider
   - **Automatic**: Controller adjusts speed based on sensor readings
3. For Manual mode: Use slider to set desired fan speed (0-100%)

Step 4: Start Simulation

1. Click **Start** button in Simulation tab
2. Watch the 3D view as smoke particles are generated and move
3. Monitor sensor readings in real-time on the right panel
4. Observe graphs updating automatically

Step 5: Analyze Results

1. Switch to **Statistics** tab to see summary
2. Look for:
   - Peak PPM values
   - Time to clear the room
   - Average air quality
3. Export data to CSV for detailed analysis

Configuring Sensors

Sensor Pair Concept

Each sensor pair consists of:
- **Low Sensor** (Green): Placed at breathing level (~3ft)
- **High Sensor** (Red): Placed near ceiling where smoke accumulates (~12ft)

Placement Guidelines

Distance from Fan

- **Close (5-15ft)**: Detects smoke being drawn to fan
- **Medium (20-40ft)**: Monitors mid-room conditions
- **Far (45-65ft)**: Checks front of room (farthest from fan)

Height Guidelines

- **Low Sensor**: 2-4 feet (breathing/sitting level)
- **High Sensor**: 10-16 feet (smoke accumulation zone)
- **Minimum separation**: 2 feet between low and high

Strategic Placement Examples

Configuration 1: Single Pair (Minimum)

- **Pair 1**: 30ft from fan, Low:3ft, High:12ft
- General room monitoring

Configuration 2: Three Pairs (Recommended)

- **Pair 1**: 15ft from fan, Low:3ft, High:12ft (Near fan)
- **Pair 2**: 35ft from fan, Low:3ft, High:12ft (Middle)
- **Pair 3**: 60ft from fan, Low:3ft, High:12ft (Far end)
- Provides comprehensive coverage

Configuration 3: Four Pairs (Maximum Coverage)

- **Pair 1**: 10ft from fan, Low:3ft, High:15ft
- **Pair 2**: 25ft from fan, Low:3ft, High:12ft
- **Pair 3**: 45ft from fan, Low:3ft, High:12ft
- **Pair 4**: 65ft from fan, Low:3ft, High:10ft
- Maximum spatial resolution

Fan Control

Manual Mode

In manual mode, you have direct control:
1. Select “Manual” from Fan Mode dropdown
2. Use the slider to set fan speed (0-100%)
3. Fan will ramp to target speed gradually
4. Monitor CFM and velocity in Fan Information panel

Use Cases for Manual Mode:
- Testing specific fan speeds
- Demonstrating fan effectiveness
- Baseline comparisons
- When you want consistent, predictable behavior

Automatic Mode

In automatic mode, the controller manages fan speed:
1. Select “Automatic” from Fan Mode dropdown
2. Controller monitors all sensor pairs
3. Adjusts fan speed based on smoke levels
4. Uses PID control for smooth response

How Automatic Control Works:

1. **Low Sensors** determine if air quality is acceptable
   - Below threshold → Consider turning off fan
   - Above threshold → Keep fan running

2. **High Sensors** determine required fan power
   - Higher smoke concentration → Higher fan speed
   - Uses worst-case sensor reading

3. **Control Logic:**
   ```
   PPM < 50:         20% fan speed (minimum)
   PPM 50-150:       40% fan speed (moderate)
   PPM 150-300:      70% fan speed (high)
   PPM > 300:        100% fan speed (maximum)
   ```

4. **Safety Features:**
   - Minimum run time of 30 seconds
   - Gradual ramp up/down
   - Won’t turn off if low sensors detect smoke

Interpreting Results

Key Metrics

PPM (Parts Per Million)

Indicates particle concentration in air:
- **0-50**: Clean/Good air quality

- **50-150**: Moderate (noticeable but acceptable)
- **150-300**: Unhealthy (uncomfortable)
- **300+**: Very unhealthy (poor visibility)

Air Clarity (%)

Indicates visual transmission:
- **100%**: Perfect visibility
- **85-100%**: Slight haze
- **60-85%**: Noticeable haze
- **40-60%**: Heavy smoke
- **<40%**: Very dense smoke

Understanding the Graphs

PPM Over Time Graph

- Shows particle concentration trends
- Multiple lines represent different sensors
- Room average shown in white
- **What to look for:**
- Rate of PPM increase (with smokers active)
- Rate of PPM decrease (when fan is on)
- Differences between sensor locations

Clarity Over Time Graph

- Mirrors PPM but from visibility perspective
- Higher is better
- **What to look for:**
- How quickly visibility degrades
- How quickly fan restores visibility
- Which areas clear first

Fan Speed Over Time Graph

- Shows fan controller behavior
- In auto mode, shows how controller responds
- **What to look for:**
- Response time to smoke detection
- Speed variations during clearing
- Patterns in control strategy

Statistics Panel

Key statistics to review:

- **Peak PPM**: Highest concentration reached
- Lower is better
- Indicates worst-case scenario
- **Average PPM**: Overall air quality
- Indicates typical conditions
- Useful for comparing configurations

- **Time to Clear**: Seconds to reach clean air
- Critical metric for fan sizing
- Lower is better
- **Current Values**: Real-time conditions
- Monitor during simulation

Comparing Configurations

To optimize your setup:

1. **Run baseline**: Default configuration
2. **Change one variable**:
   - Number of smokers
   - Sensor locations
   - Fan control strategy
3. **Compare statistics**:
   - Time to clear
   - Peak PPM
   - Average PPM
4. **Export data** for detailed analysis

Advanced Features

Simulation Speed Control

Adjust how fast the simulation runs:
- **1.0x**: Real-time (1 second = 1 second)
- **2.0x**: Double speed
- **5.0x**: Five times faster
- **0.5x**: Half speed (for detailed observation)

Use Cases:
- Fast speed: Quick testing of long-term scenarios
- Slow speed: Detailed observation of smoke behavior
- Real-time: Accurate timing measurements

Configuration Management

Saving Configurations

1. Set up sensors and simulation parameters
2. Click “Save Configuration” in Simulation tab
3. Choose filename and location
4. Configuration saved as JSON file

Saved Settings Include:
- All sensor pair locations
- Number of smokers
- Fan control mode
- Simulation speed

Loading Configurations

1. Click “Load Configuration”
2. Select saved JSON file
3. System resets and applies saved configuration
4. Ready to run simulation

Use Cases:
- Save different scenarios for testing
- Share configurations with colleagues
- Return to previous tests
- Document optimization process

Data Export

CSV Export

1. Run a simulation
2. Go to Statistics tab
3. Click “Export Data to CSV”
4. File saved to `exports/` directory

CSV Contains:
- Timestamp for each data point
- Fan speed at each moment
- Room average PPM and clarity
- Individual sensor readings (PPM and clarity)
- Particle count

Analysis Options:
- Import into Excel or Google Sheets
- Use Python/R for statistical analysis
- Create custom visualizations
- Generate reports

3D View Controls

Navigation

- **Rotate**: Click and drag with left mouse button
- **Zoom**: Scroll mouse wheel
- **Pan**: (currently not implemented)

View Options

Visible elements (currently always on):
- Room boundaries with floor grid
- Smoke particles (gray points)
- Sensors (green=low, red=high)
- Exhaust fan (blue circle)

Tips for Better Viewing:
- Rotate to see smoke flow toward fan
- Zoom in to see sensor details
- Zoom out for overall room view
- Side view shows stratification clearly

Keyboard Shortcuts

(Note: These require focus on specific widgets)

- **Space**: Start/Pause (when focused on button)
- **+/-**: Adjust values in spinboxes
- **Tab**: Navigate between controls
- **Enter**: Activate focused button

Tips and Best Practices

Getting Meaningful Results

1. **Start Simple**
   - Begin with 1 sensor pair
   - Use medium number of smokers (24)
   - Run in real-time (1x speed)

2. **Add Complexity Gradually**
   - Add more sensor pairs
   - Try different locations
   - Experiment with fan modes

3. **Test Systematically**
   - Change one variable at a time
   - Keep notes on configurations
   - Save configurations before changing

4. **Use Statistics**
   - Focus on “Time to Clear” metric
   - Compare peak PPM values
   - Look at sensor-to-sensor differences

Common Scenarios

Scenario 1: Initial Assessment

Goal: Understand current room performance
- Use 48 smokers (full capacity)
- Place 2-3 sensor pairs
- Run in auto mode
- Export results as baseline

Scenario 2: Optimize Fan Control

Goal: Find best automatic control strategy
- Fixed smoker count (24)
- Multiple sensor locations
- Compare auto vs manual at different speeds
- Measure time to clear

Scenario 3: Sensor Placement Study

Goal: Find best sensor locations
- Fixed fan speed (manual mode)
- Test different sensor positions
- Compare detection times
- Find earliest warning positions

Troubleshooting

Simulation Runs Slowly

- Reduce number of smokers
- Lower simulation speed
- Close other applications

Particles Not Visible

- Zoom in to room
- Wait for particles to generate
- Check that simulation is running

Fan Not Responding

- Check if in Manual mode
- Verify slider is not at 0%
- In Auto mode, check if sensors detect smoke

Sensors Show No Readings

- Ensure simulation is running
- Wait for smoke to reach sensors
- Check sensor placement (inside room?)

Appendix: Technical Details

Physics Model Summary

The simulation uses particle-based computational fluid dynamics:

1. **Particle Generation**: 500 particles/cigar/second
2. **Forces Applied**:
   - Buoyancy (upward, temperature-based)
   - Diffusion (random dispersion)
   - Advection (fan suction)
   - Gravity (cooling particles)
3. **Boundary Conditions**: Elastic collisions with walls
4. **Removal**: Particles removed at fan or after 5 minutes

Accuracy and Limitations

What the Simulation Does Well:
- General smoke movement patterns
- Relative comparisons between configurations

- Fan effectiveness demonstration
- Sensor placement optimization

Limitations:
- Simplified turbulence model
- No HVAC inlet modeling (yet)
- Uniform particle size
- Ideal mixing assumptions
- No temperature gradients (except buoyancy)

For Production Use:
- Use as design tool, not final specification
- Validate with real-world measurements
- Consider CFD analysis for critical applications
- Factor in safety margins

Support and Feedback

For questions, issues, or suggestions:
- Review README.md for technical details
- Check this guide for usage questions
- Examine example configurations in `configs/` directory

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