THUNDERHEAD ENGINEERING

Model Research and Development

R&D Activity at Thunderhead Engineering 2021-2022

Product Evolution

FDS 6.7.5, 6.7.6, 6.7.9

FDS 7 Preparation

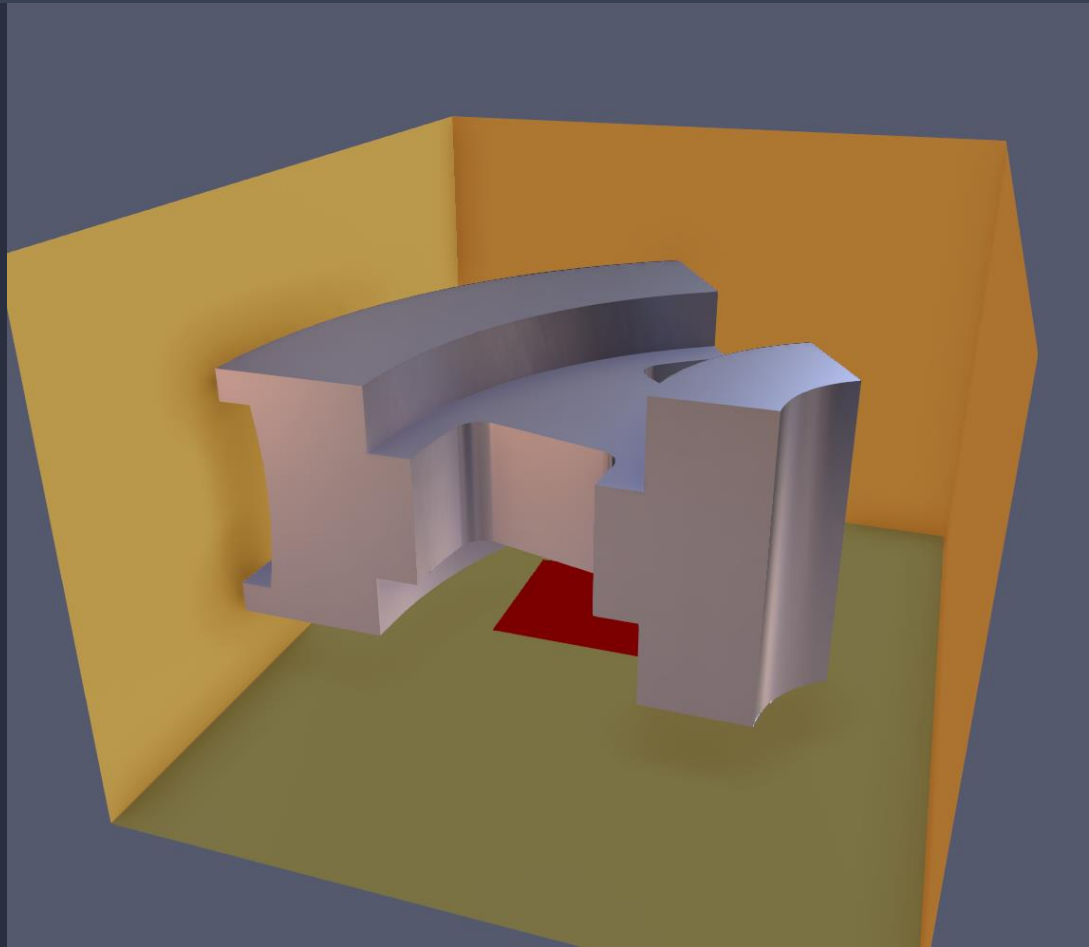
Scenario Updates

Math Controls

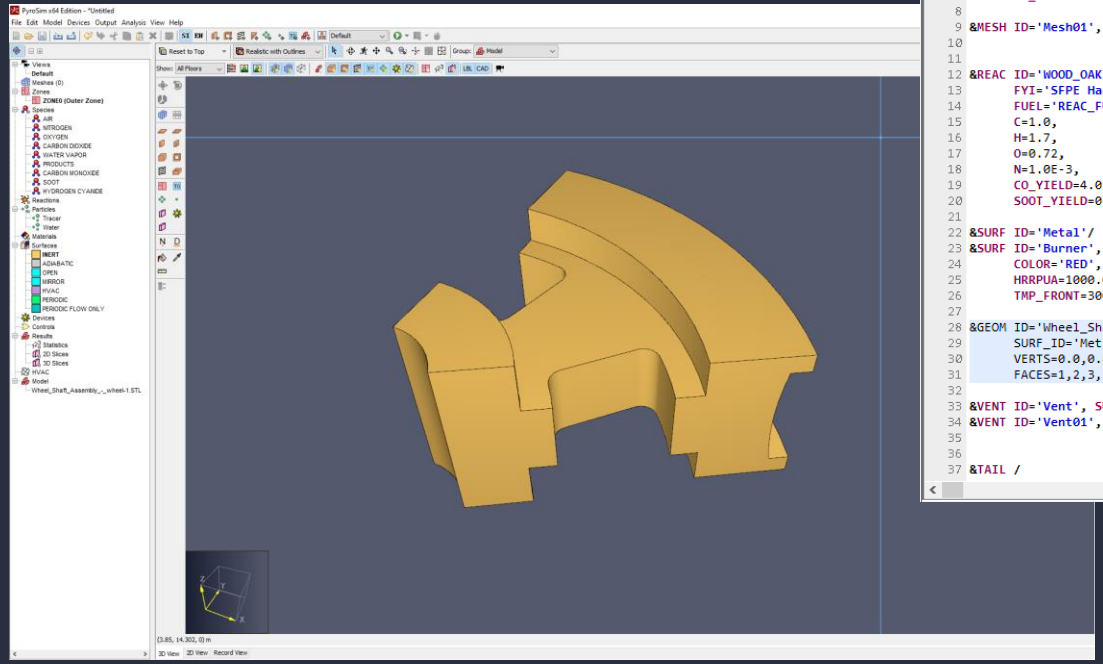
Mesh Partitioning/Alignment

Cloud FDS Updates

PyroSim



FDS 7 – GEOM



Model Records (Read-Only):

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Sep 9, 2022 10:56:01 AM

&HEAD CHID='Wheel_Shaft_Assembly_-_wheel-1'/
&TIME T_END=10.0/
&DUMP DT_RESTART=300.0, DT_SL3D=0.25/

&MESH ID='Mesh01', IJK=32,27,20, XB=-1.4,5.0,-0.4,5.0,0

&REAC ID='WOOD_OAK',
      FYI='SFPE Handbook, 5th Ed',
      FUEL='REAC_FUEL',
      C=1.0,
      H=1.7,
      O=0.72,
      N=1.0E-3,
      CO_YIELD=4.0E-3,
      SOOT_YIELD=0.015/

&SURF ID='Metal'/
&SURF ID='Burner',
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      FACES=1,2,3,1,2,1,4,1,3,2,5,1,6,1,3,1,4,1,7,1,5,2,4,1,8,3,5,1,6,7,1,1,6,3,9,1,4,7,10,1,5,4,11,1,9,3,8,1,8,

&VENT ID='Vent', SURF_ID='Burner', XB=1.8,3.2,1.4,3.4,0.0,0.0/
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&TAIL /
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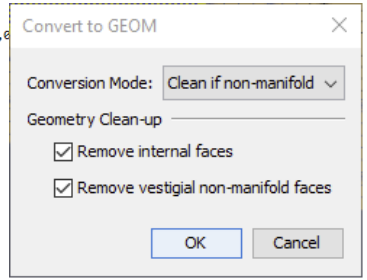
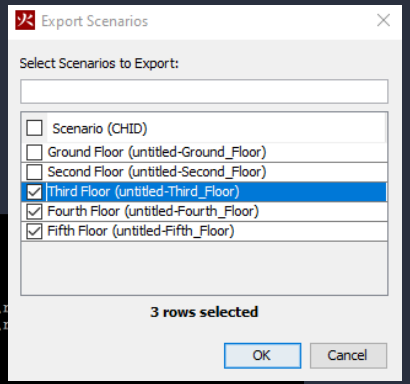


Scenario Updates

- Use a single PyroSim model for multiple FDS simulations
- Enable/Disable items for each Scenario
  - Burners, Vents, Obstructions, Meshes, Devices
- Export selected scenarios to batch files for automation

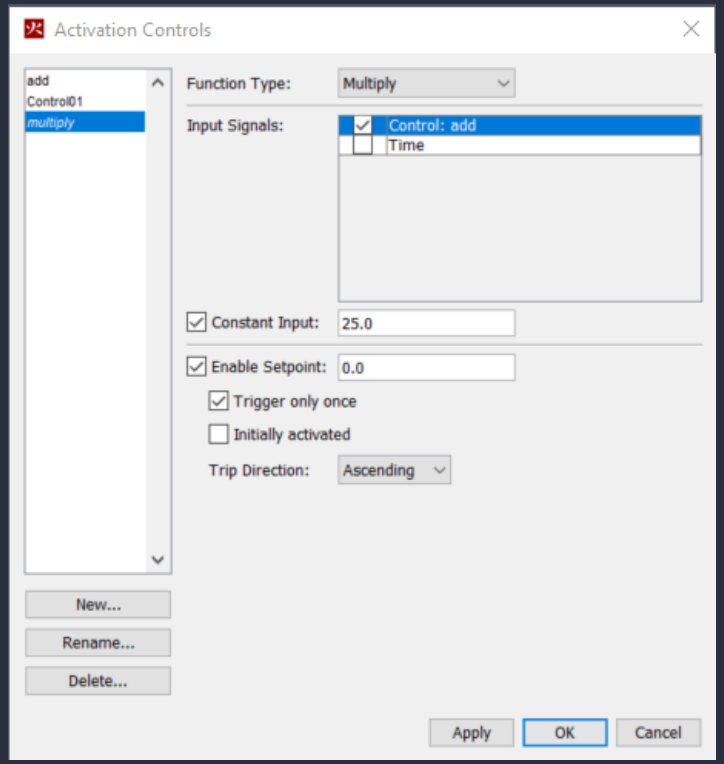



```
@SETLOCAL
@ECHO off
@ECHO [%~n0] Beginning at %time%

SET PATH=
SET PATH=%PATH%;C:\Downloads\PyroSim-2021-4-1112-x64-en\r
SET PATH=%PATH%;C:\Downloads\PyroSim-2021-4-1112-x64-en\r
SET PATH=%PATH%;C:\WINDOWS
SET PATH=%PATH%;C:\WINDOWS\system32

SET I_MPI_WAIT_MODE=1
SET OMP_NUM_THREADS=1
SET OMP_STACKSIZE=16M


ECHO [%~n0] Scenario "Third Floor" beginning at %time%
PUSHD untitled-Third_Floor
runfds.exe mpiexec.exe -n 1 -localonly
C:\Downloads\PyroSim-2021-4-1112-x64-en\release64-en\fds\fds.exe untitled-Third_Floor.fds
POPD

ECHO [%~n0] Scenario "Fourth Floor" beginning at %time%
PUSHD untitled-Fourth_Floor
runfds.exe mpiexec.exe -n 1 -localonly
C:\Downloads\PyroSim-2021-4-1112-x64-en\release64-en\fds\fds.exe untitled-Fourth_Floor.fds
POPD

ECHO [%~n0] Scenario "Fifth Floor" beginning at %time%
PUSHD untitled-Fifth_Floor
runfds.exe mpiexec.exe -n 1 -localonly
C:\Downloads\PyroSim-2021-4-1112-x64-en\release64-en\fds\fds.exe untitled-Fifth_Floor.fds
POPD

ECHO [%~n0] Completed at %time%
pause
```

Mathematical Controls

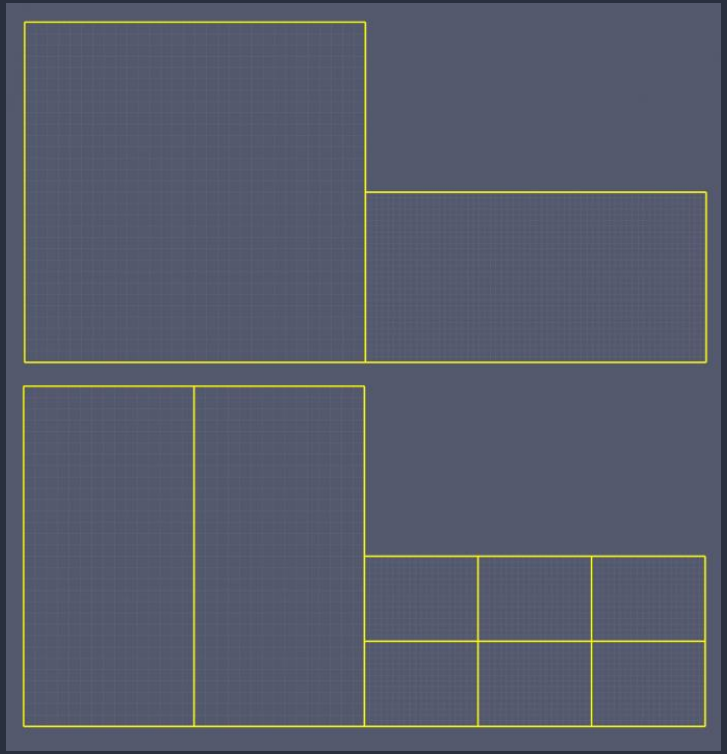
Mathematical controls apply simple math operations on the selected input signals. Input signals may be any of Time, the output value of a device, a constant value, or the output of another Mathematical control

- Exponential
- Logarithm
- Cosine
- Sine
- Arccosine
- Arcsine
- Arctangent
- PID
- Percentile
- Subtract
- Multiply
- Divide
- Power
- Sum
- Maximum
- Minimum



Mesh Partitioning and Alignment

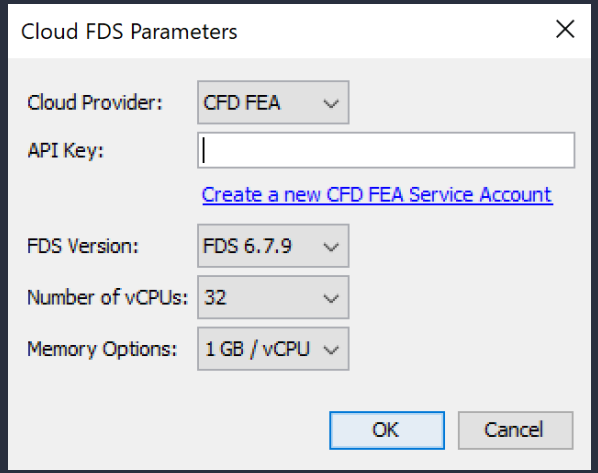
- Divide selected meshes into 2-96 partitions
- Assists with preparation of parallel/cloud simulations
- Meshes assigned to processors based on cells per processor instead of round-robin



Example creating 8 mesh partitions from an original selection of 2 meshes.

Cloud FDS Updates

- Multiple FDS Versions Supported
  - FDS 6.7.0 – 6.7.9
- Updated processor assignment
- View and Download Results from Cloud Jobs



Product Evolution

- Inferred Stairs
- Queues
- Attractors
- Occupant Targets
- Obstacles

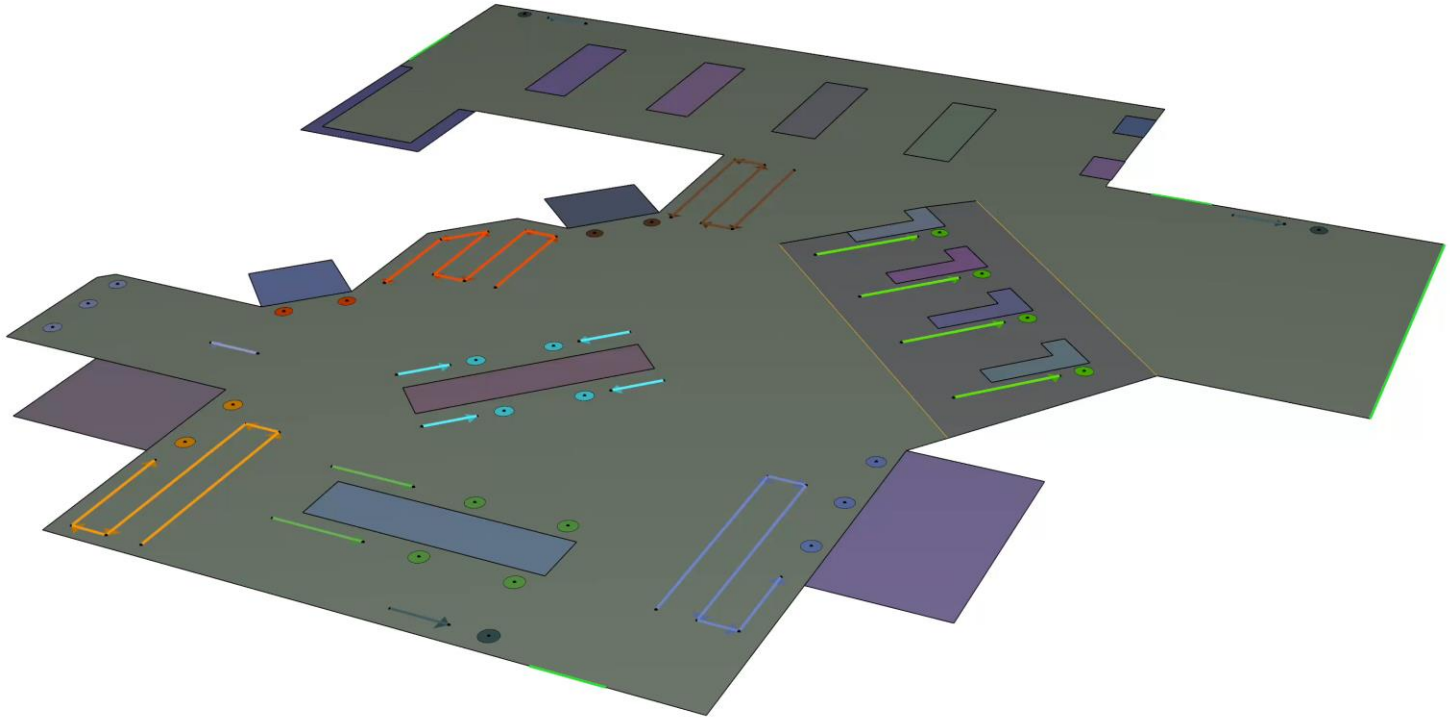
Pathfinder

Inferred Stair Geometry

- Previously, non-stair geometry used level-terrain movement speeds
- Stair-like geometry now inferred as occupant approaches a change in elevation
- Generally found in more complex models with shallow stairs
  - Auditoriums
  - Stadiums
  - Outdoor areas with varying elevation

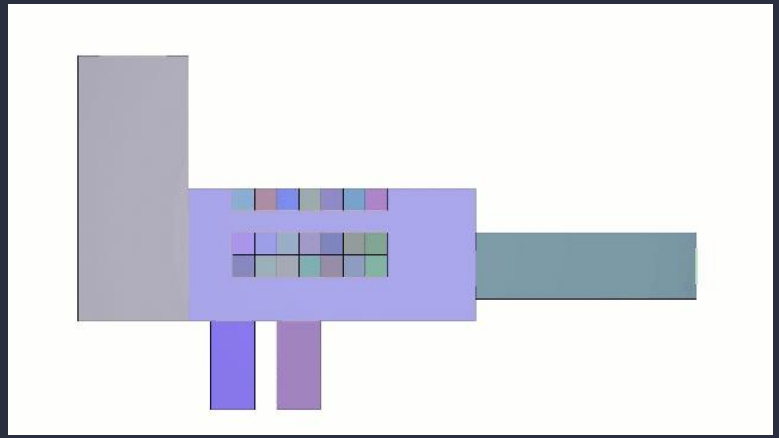
Queues

- Service location combined with queuing path
- Can model a variety of complex behaviours
- Improved queue representation in Results viewer
  - Queue Paths
  - Occupant queue state



Attractors

- Optional behavior modifiers acting on selected regions and population groups (profiles)
- Side quests for agents
  - Restroom, concessions, art viewing, etc.
- Terminal behaviors provided increased flexibility

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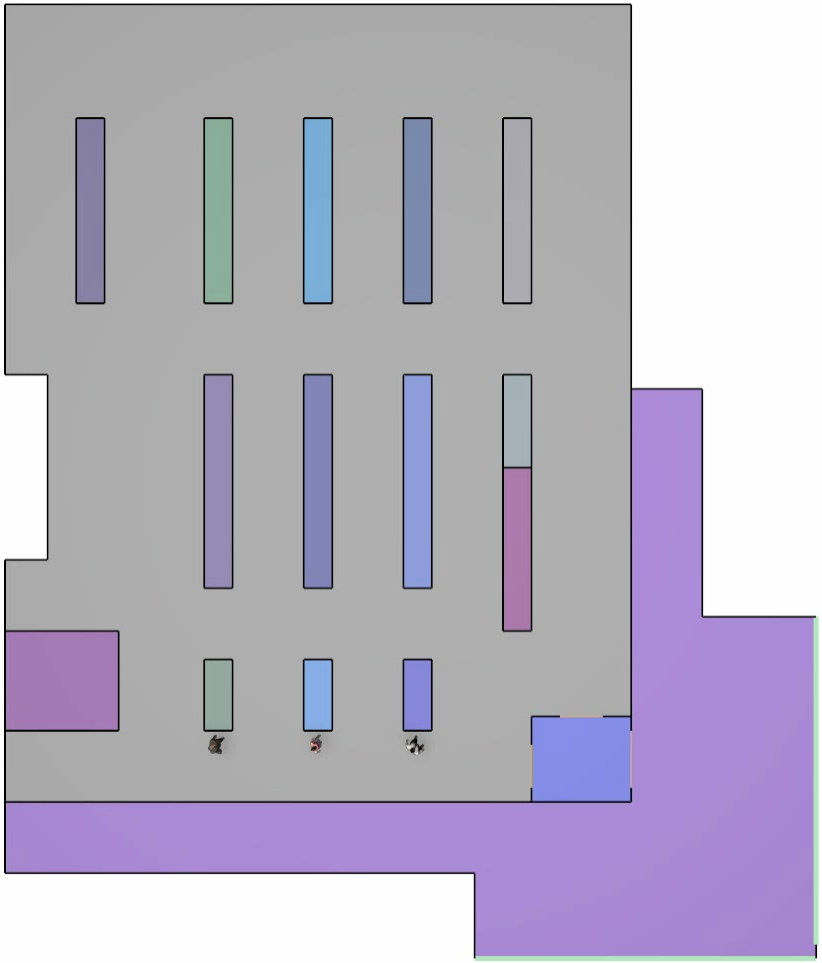

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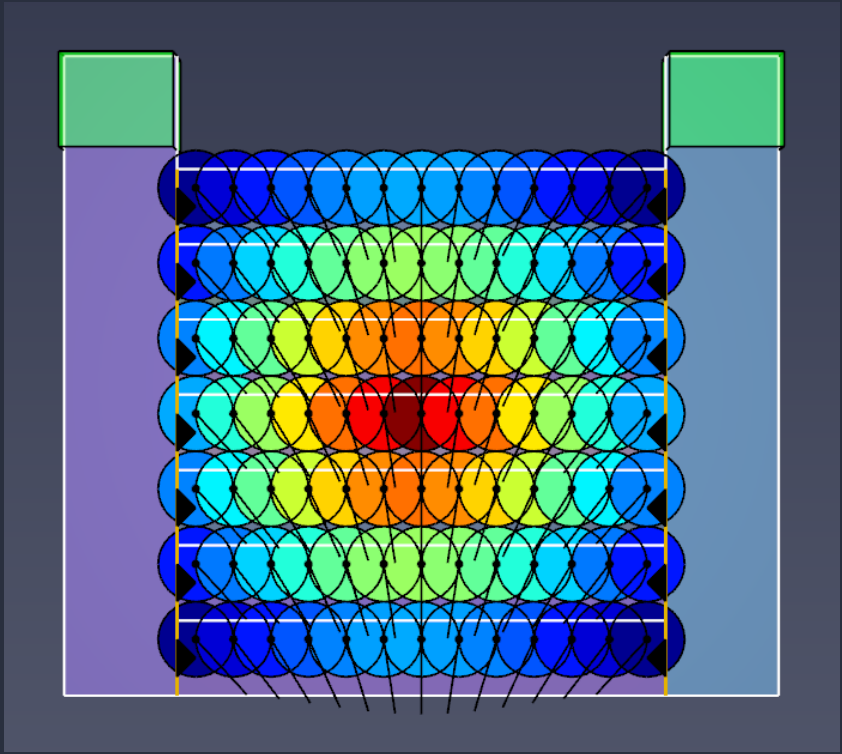
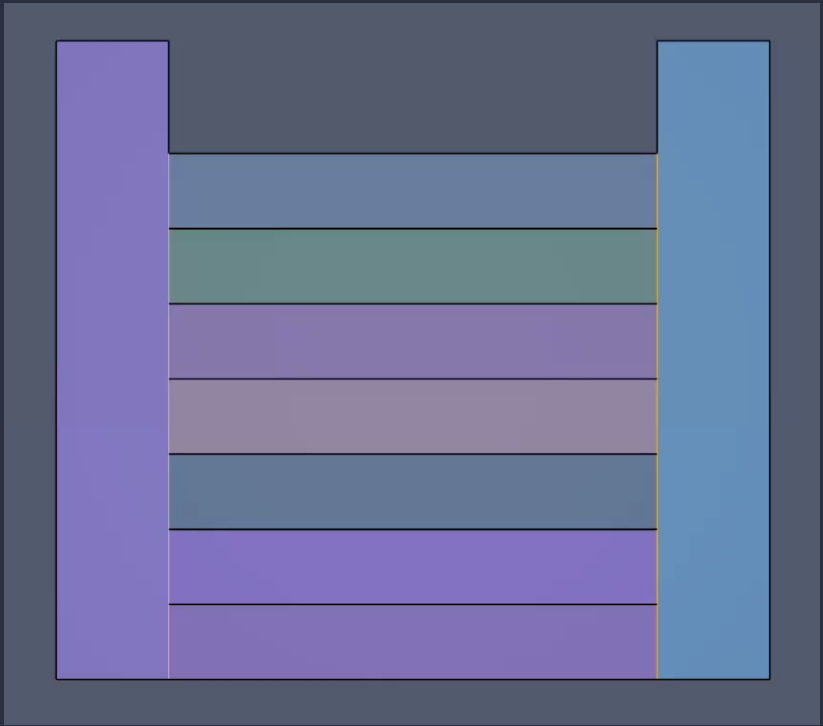
Occupant Targets

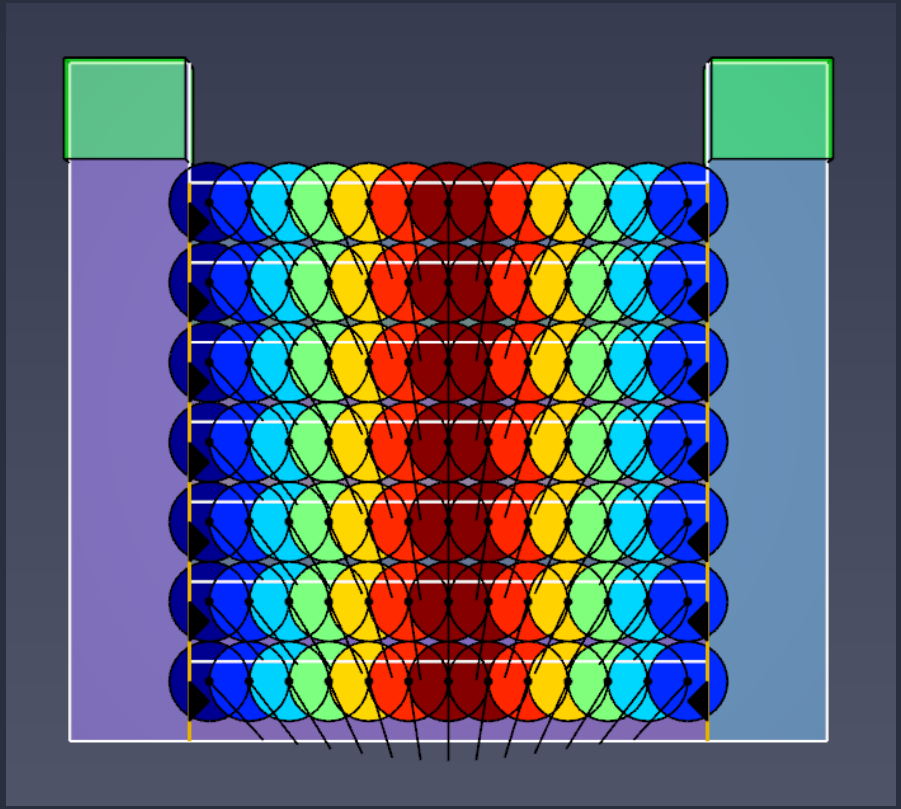
- Location on the movement mesh which can be occupied by an agent
  - Seating
  - Refuge
  - Assisted evacuation
- Location can optionally be reserved while agent is away
- Includes orientation and filling priority

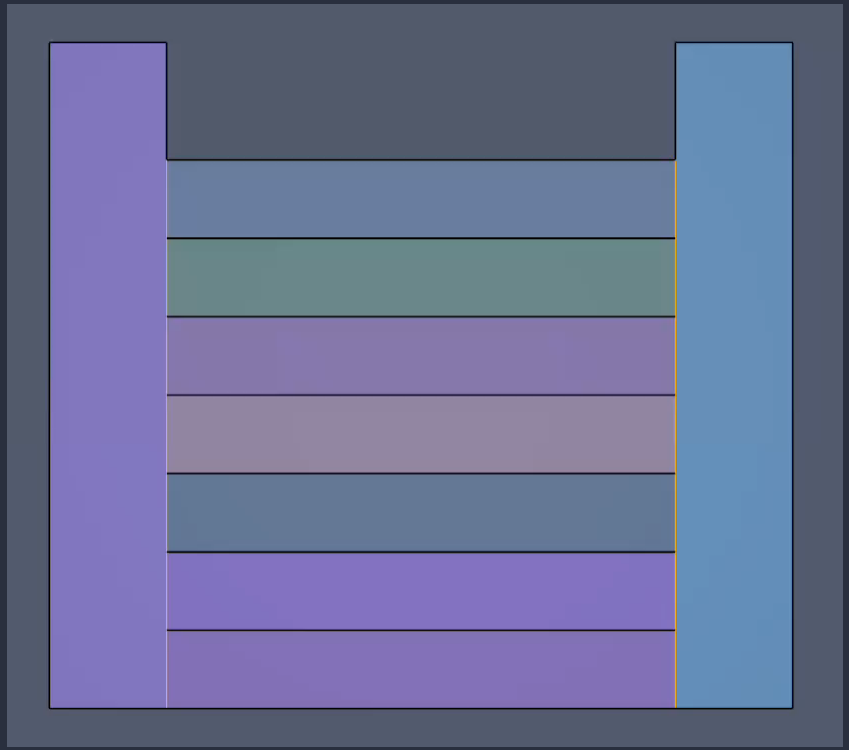
Target Priority



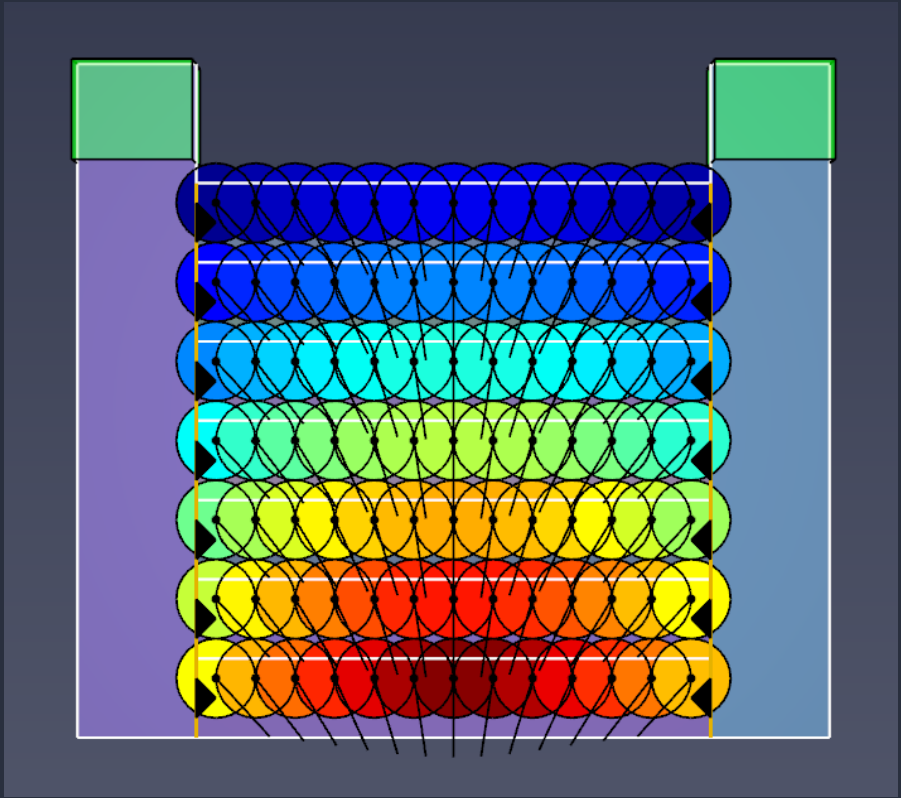


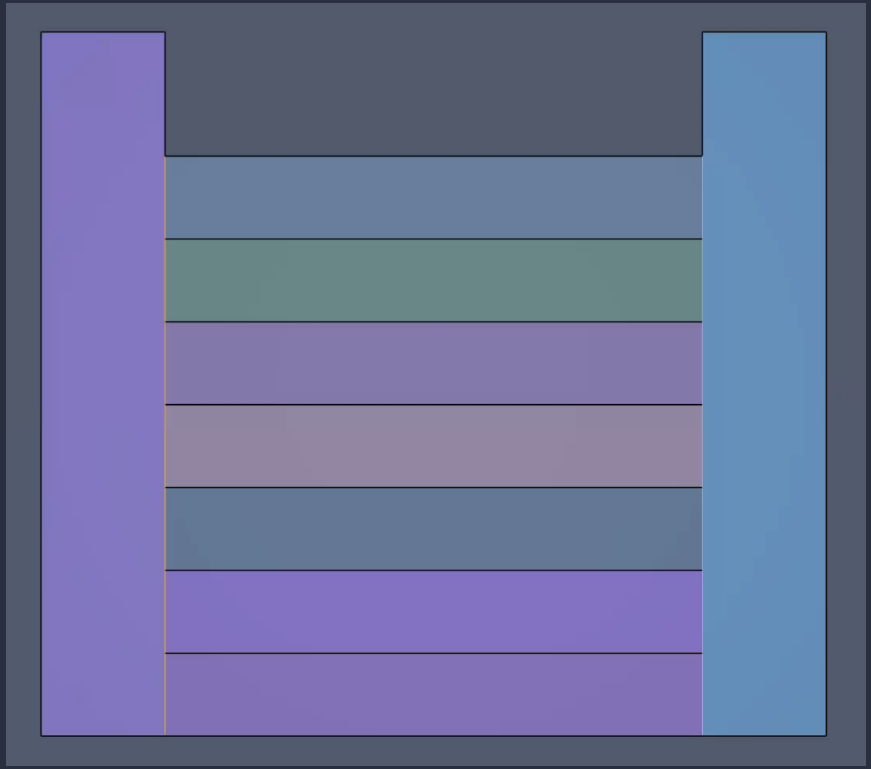
Target Priority





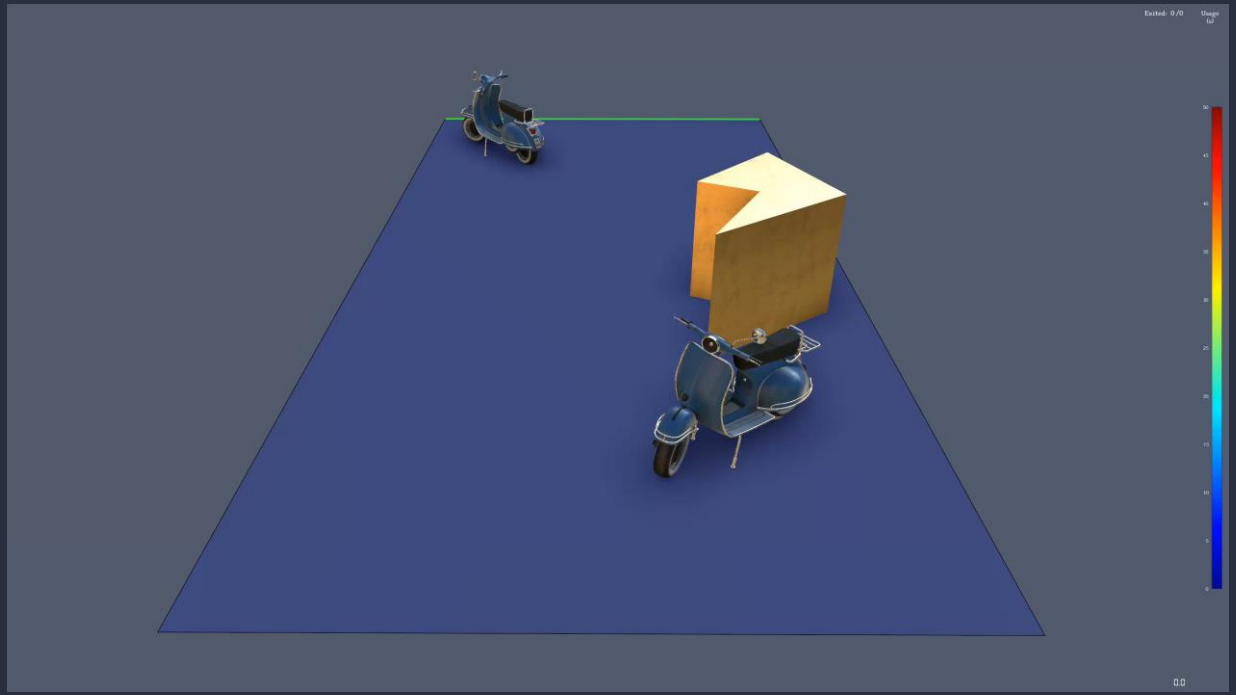
Target Priority

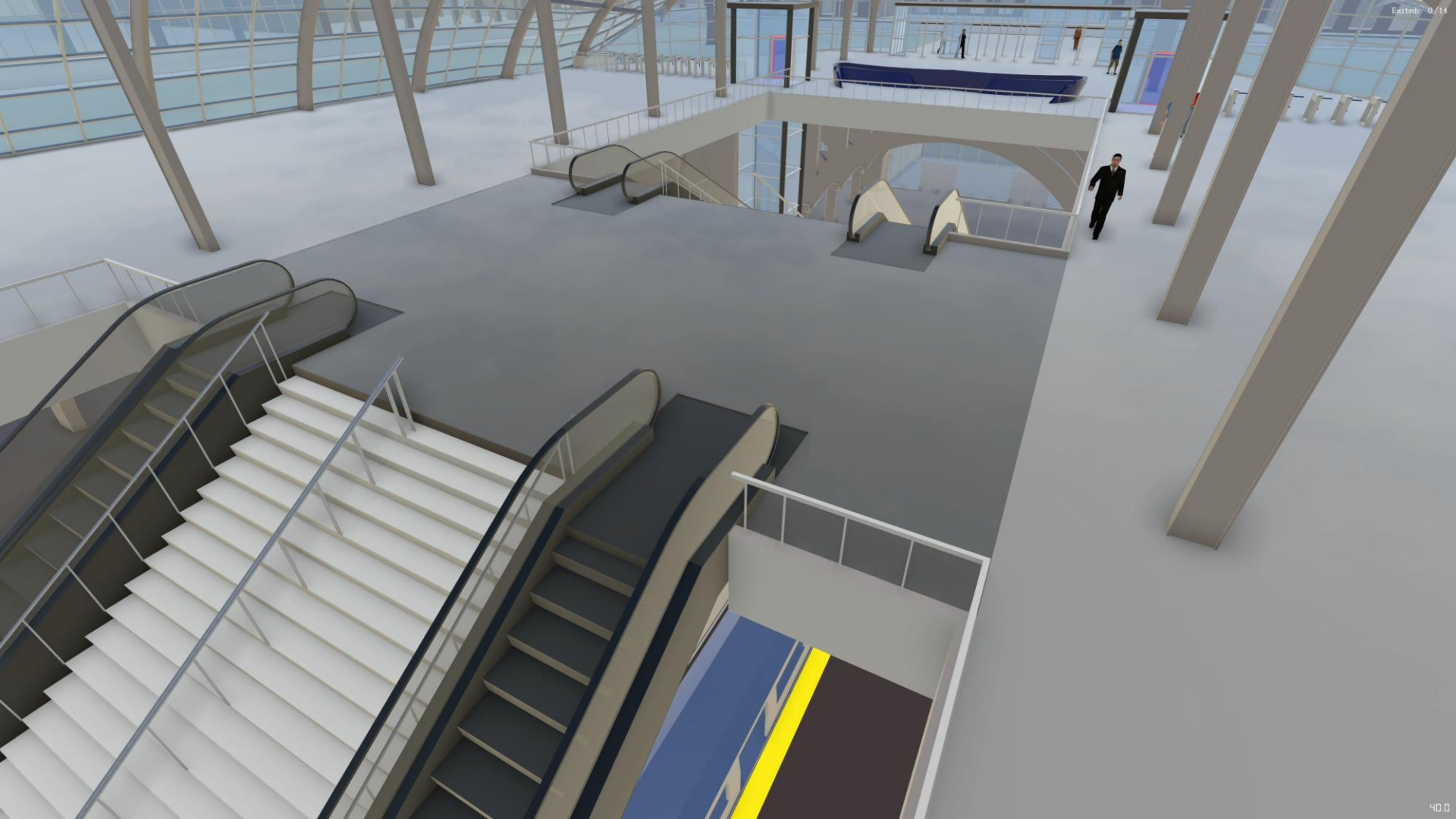




Obstacles

- Transient area that can impede or completely block occupants
  - Hazards
  - Debris
  - Crowd Control
- Can be represent as extruded area or imported CAD geometry

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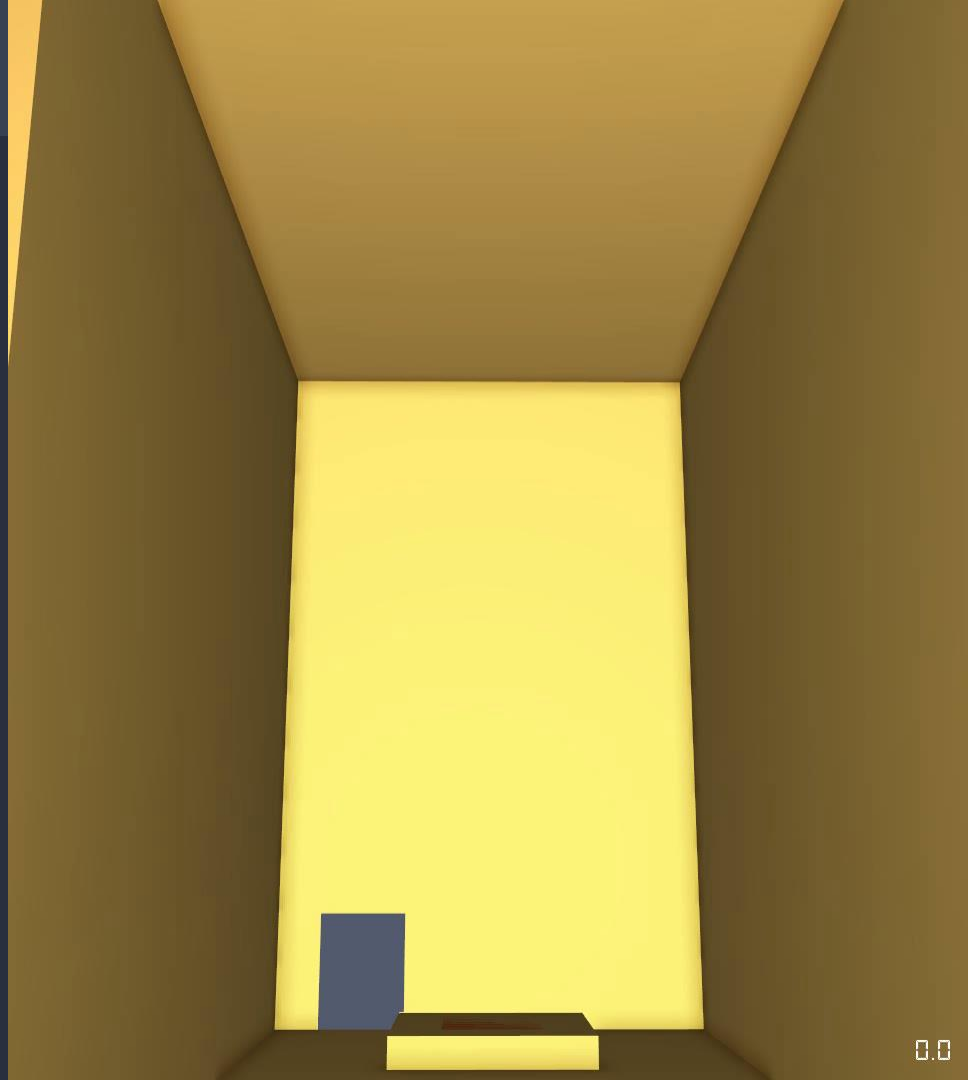
Results Visualization

- Smoke/Fire Lighting
- Image Based Lighting
- Physically Based Rendering
- Proximity Analysis
- Updated Social Linkage Contours
- 360 Movie Export



Smoke and Fire Lighting


PyroSim
Petra


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Image Based Lighting

Physically Based Rendering (PBR)

Proximity Analysis

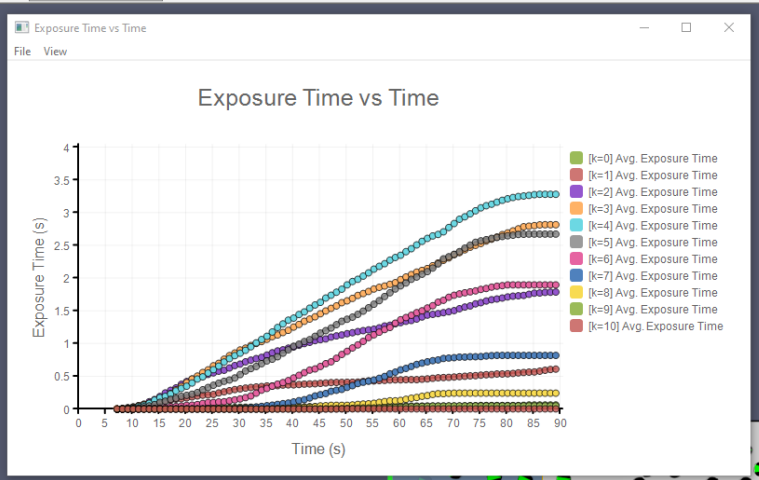
- Occupant exposure calculation based on the EXPOSED model
  - Ronchi, Enrico, and Ruggiero Lovreglio. 2020. “EXPOSED: An Occupant Exposure Model for Confined Spaces to Retrofit Crowd Models during a Pandemic.” Safety Science 130: 104834. https://doi.org/https://doi.org/10.1016/j.ssci.2020.104834.
- Alternative to simple risk assessment based on simple social distance

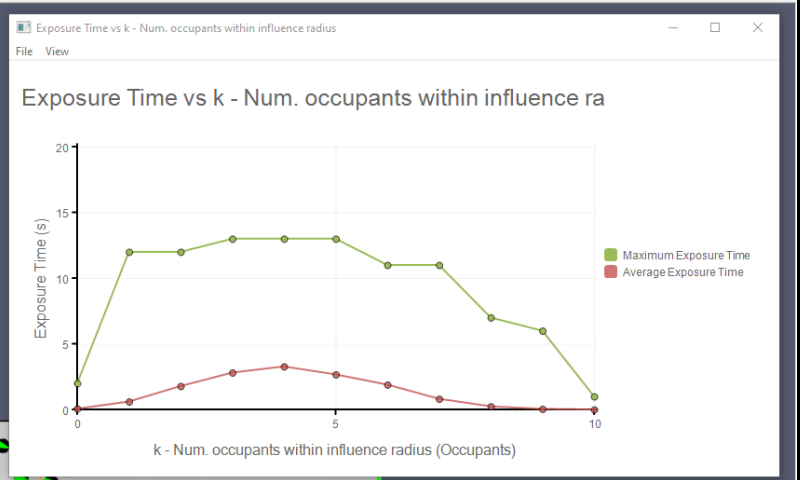
Pathfinder 2022 x64 - *uo_experiment-300-300-300.pfrv - uo_experiment-300-300-300.pfr

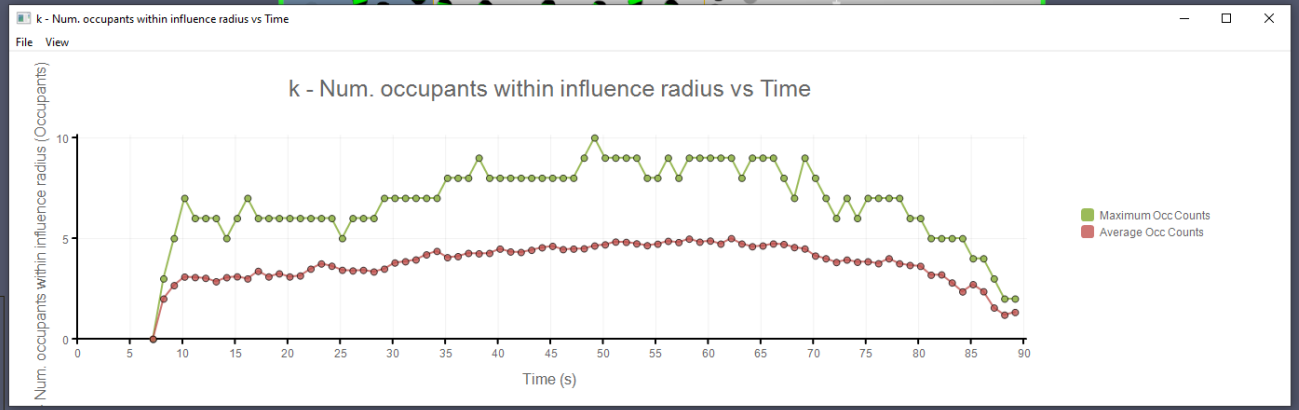
File Edit Analysis View Help

Realistic with Outl

- Views
  - Default
- Scene Geometry
  - Nav Mesh
- Dimensions
  - Dimension 8.000000 m
  - Dimension 3.000000 m
- Labels
- Occupant Proximity
  - ProximityAnalysis
    - Occ Counts vs. Time
    - Exposure Ti... Occ Counts
    - Maximum Exp...e vs. Time
    - Average Exp...me vs. Time
- Occupant Contours
  - Density
  - Density[Average]
  - Level of Service (Queuing)
  - Level of Service (Stairway)
  - Level of Service (Walkway)
  - Normalized Speed
  - Speed
  - Speed[Average]
  - Time to Exit
  - Usage[Accumulated]
  - Usage[Instantaneous]
- Sample Points
- XY Plot Data







20.3

Repeat

20.3

Selected Group: Average Exposure Time vs. Time

Stopped | Time: 0:20 / 1:29 | Speed: 1 X | Framerate: 245.5 fps

Social Distance and Linkage Contours

- Social Distance
  - Plots distance to nearest occupant (within *R*) around location
  - Contour represents SD value of closest occupant (within R)
  - Can optionally account for group members
- Social Linkage
  - Similar to Social Distance, but plots number of occupants instead

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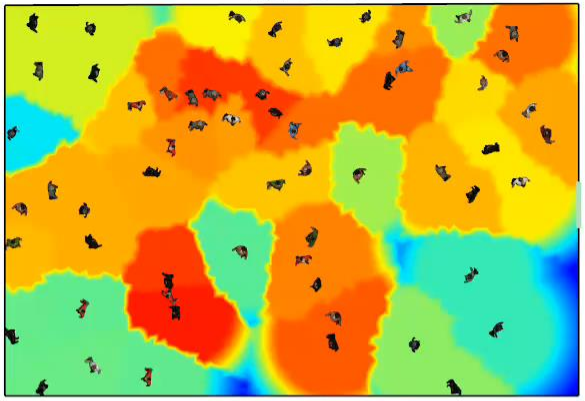
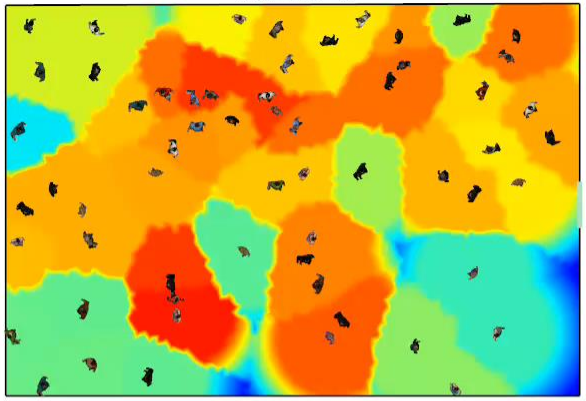
Social Distance (m)

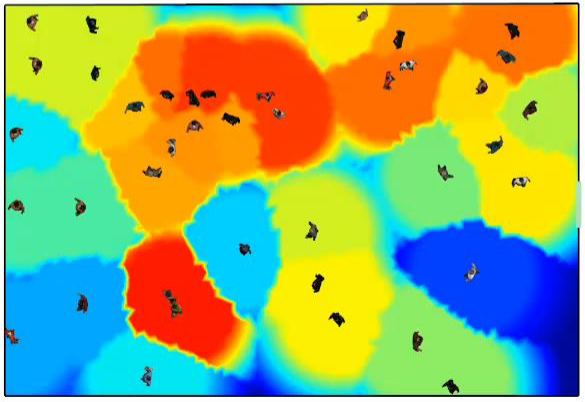
Social Distance = 1.0 m
Num Occs = 60



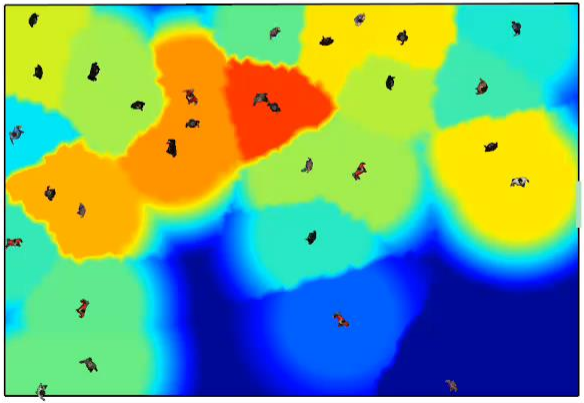
Social Distance = 2.0 m
Num Occs = 60

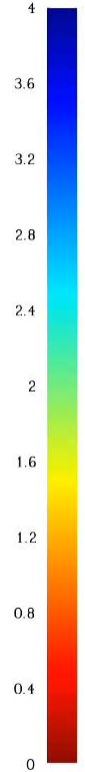


Social Distance = 3.0 m
Num Occs = 40



Social Distance = 4.0 m
Num Occs = 30





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360 Video Export

- Produces 3D movie that can be played in VR headset, phone-based VR, YouTube, or other viewers.
- Allows Sharing of more interactive 3D results visualizations without the need for PyroSim or Pathfinder Results.
- Generates full 360-cam volume around the camera point
- Follows defined camera our tour path

Click Here

Research Areas

IMFSE Sponsorship

- International Master of Science in Fire Safety Engineering
- Program contributor for 2021-2022
- Participated in FSE Day 2022
  - Wildland Fire Modeling
  - FDS, PyroSim, TERRAIN, Level Set Methods

Research Collaborations

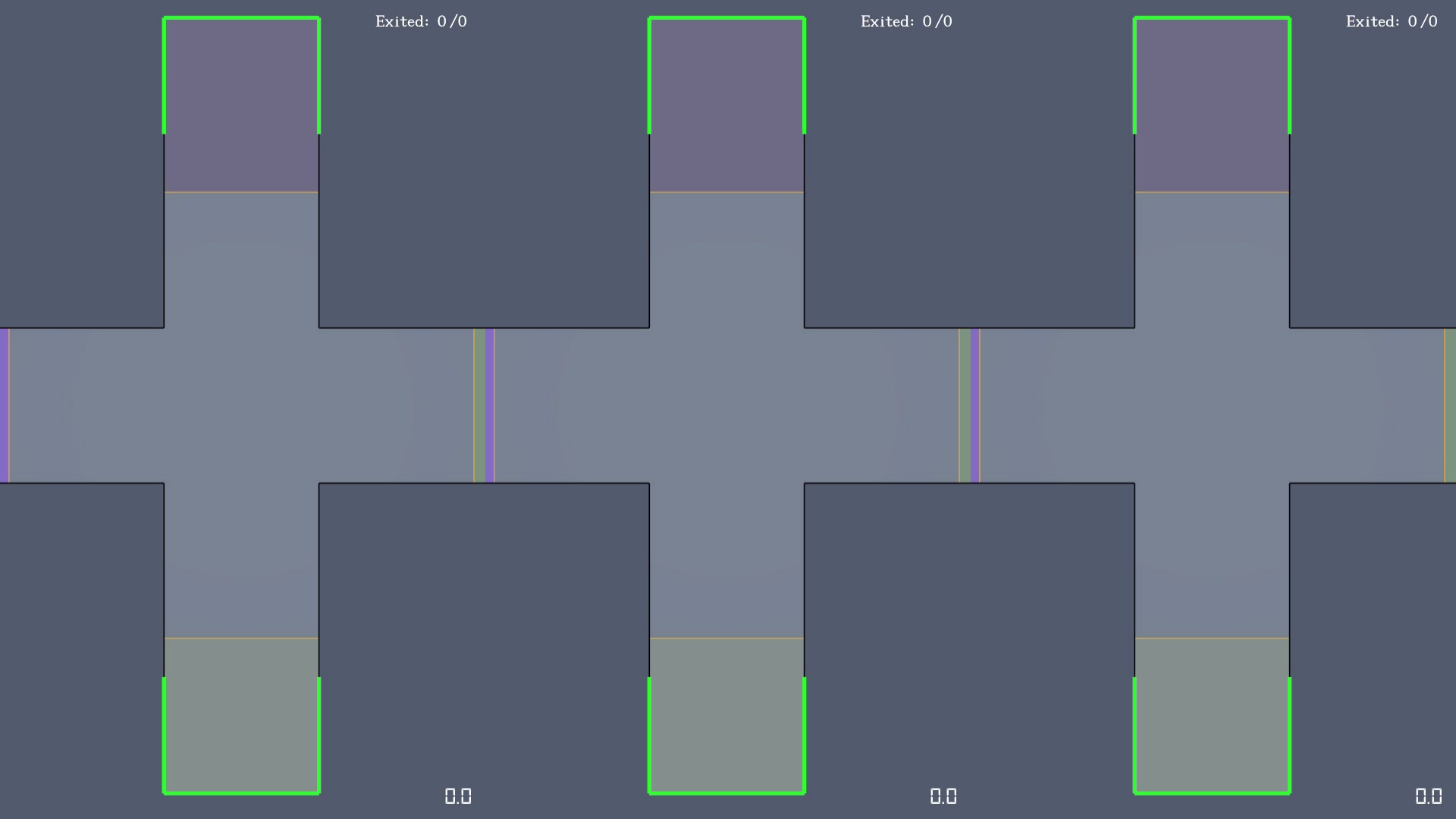
- Anne Templeton – Univ of Edinburgh
  - Steve Gwynne, Pete Thompson – GHD
  - First Responder Communication, Social Psychology
- Pete Thompson – GHD
  - Continuing BuildingSMART work – Fire Safety Engineering MVD, Occupant Movement MVD Phase 2
- Nazim Yakhou (Jensen Hughes) – Lund University, Pete Thompson and Enrico Ronchi
  - Two-way evacuation data exchange using IFC/BIM/Revit
  - Thunderhead updated Pathfinder to support and test Nazim's research

Pathfinder API for Research

- Investigating possible research API
  - Testing movement and behavior models in Pathfinder
- Collaborating with Forschungszentrum Jülich
  - Goal would be testing locomotion models with less need for framework code
- Concept could support more advanced user models with complex behavior

Crossflow and Counterflow

- Working to validate against Jülich movement experiments
- Testing alternative avoidance and collision methods
- Developed a score to compare different results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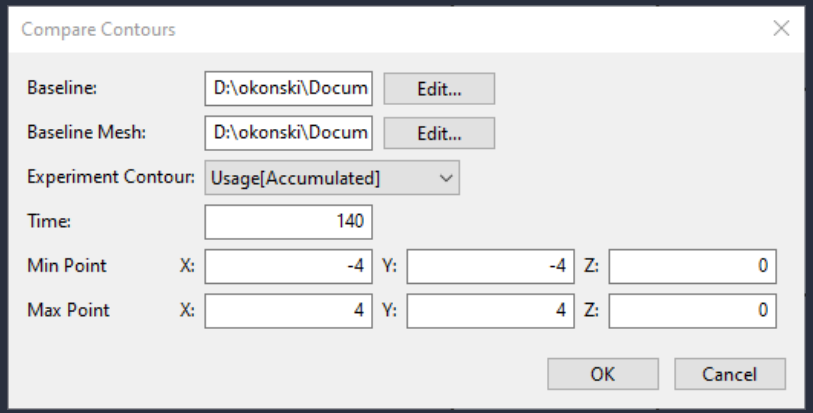
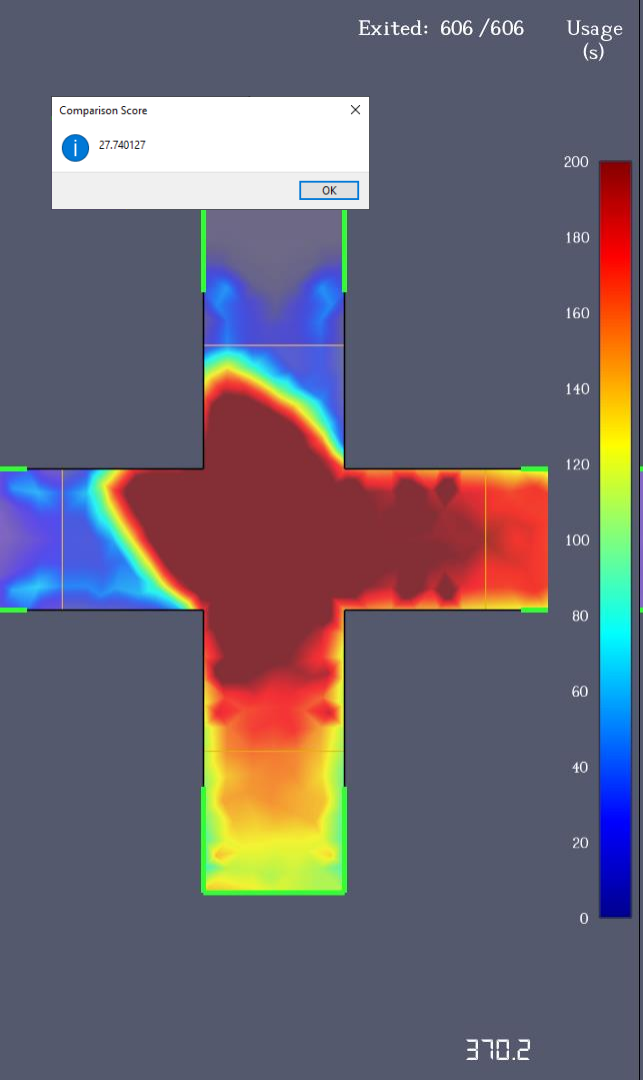
0.0

Score of Comparison to Experiments

- Using contours of Usage
- Sum of squared difference between values at contour locations




Exited: 606 /606
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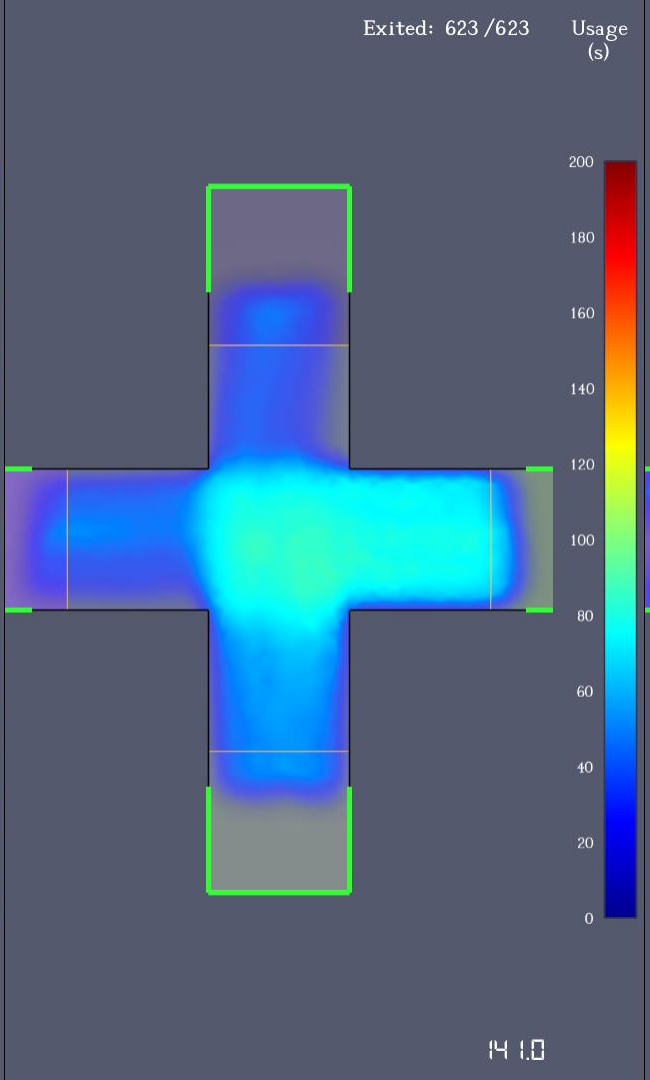
160
140
120
100
80
60
40
20
0
370.2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160
140
120
100
80
60
40
20
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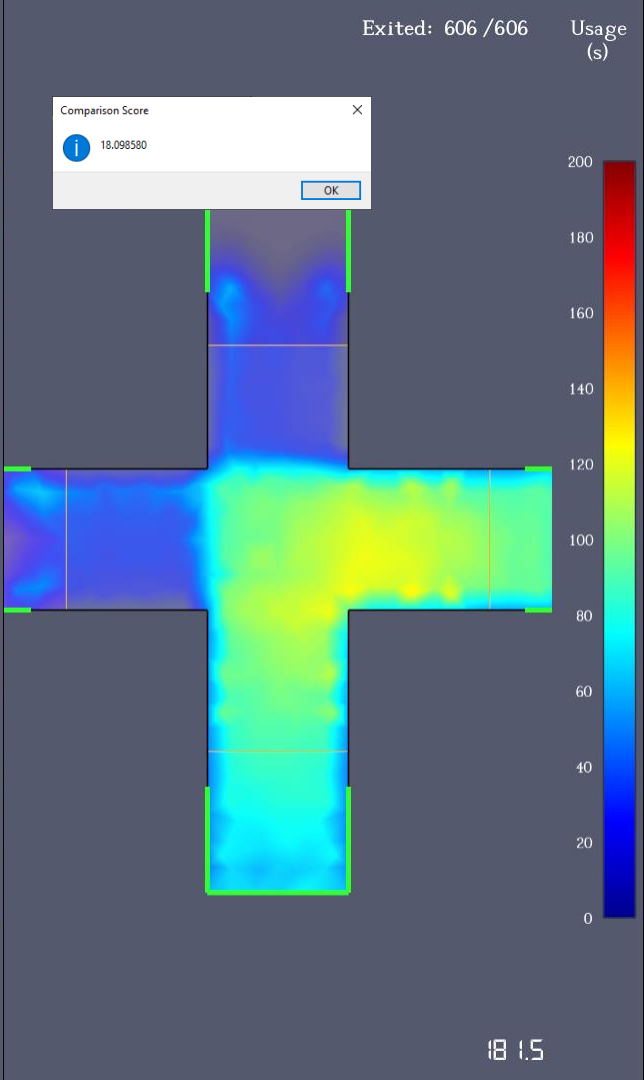
141.0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Usage (s)
Comparison Score
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OK
200
180
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140
120
100
80
60
40
20
0
181.5

CONTAM User Interface

- Zone-based contaminant transport simulator
- Widely used for pressurization studies
  - Stairs
  - Elevator Shafts
  - Atria
- Currently in prototype development phase
- Interested in user needs and early feedback

THUNDERHEAD ENGINEERING

Special Thanks

Daniel Swenson

Charlie Thornton

Richard O'Konski

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Jon Albrecht

Kyle Perkuhn

Lauren Spare

Graham Armstrong

Xiaorong Guo

Tana Warner

Eric Benson

Noah Hastings

Steven Zwahl

Ben Thompson

Kaid Mossburgh

Ethan Tucker