Complex Behavioral Modeling in Pathfinder Using Triggers

FEMTC 2024

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Review of occupant movement in Pathfinder

Description of new trigger options for controlling movement with examples
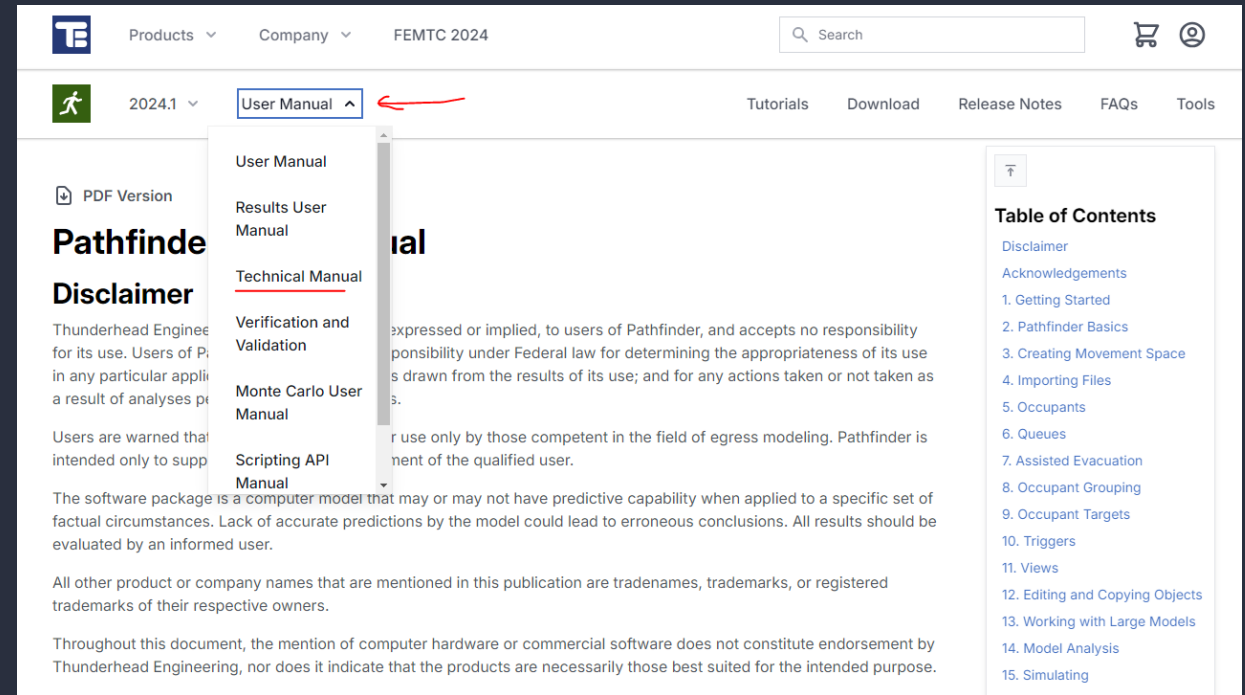
Pathfinder Movement

- Originally released in 2009 primarily as evacuation and egress simulator for in-building environments
    - Primary behavior seek the closest or fastest exit from a building
    - Also automate simple distance and flowrate-based calculations (SFPE-mode)
- Over time, more options were added including refuge rooms, occupant sources, room-filling
- Attractors were added in 2021 – allowed temporary or permanent change of behavior
- Generalized into triggers in 2023

Agent-Based Movement Algorithm

- Details found in Pathfinder Technical Reference Manual

- https://support.thunderheadeng.com/docs/pathfinder/2024-1/technical-reference-manual/

- See also the Verification and Validation guide

Agent Movement Process

- Goal Selection
  - Where to go / What to do next
- Wayfinding
  - How to find your way to the goal
- Locomotion
  - Movement – Acceleration, Velocity, turning
  - Conflict – Collision, priority, crowding

Goal Selection

- Selection of the next action or waypoint

- Driven by the specification in the Behavior

- Goal Types
  - Seek – go somewhere in the model
  - Idle – wait for time/elevator/queue
  - Instant – action that occurs in the time step

Some behaviors are implied by the type of goal:
  - Room goals cause waiting and room-filling
  - Exit goals cause evaluation of exit doors for distance/time

Goal specification
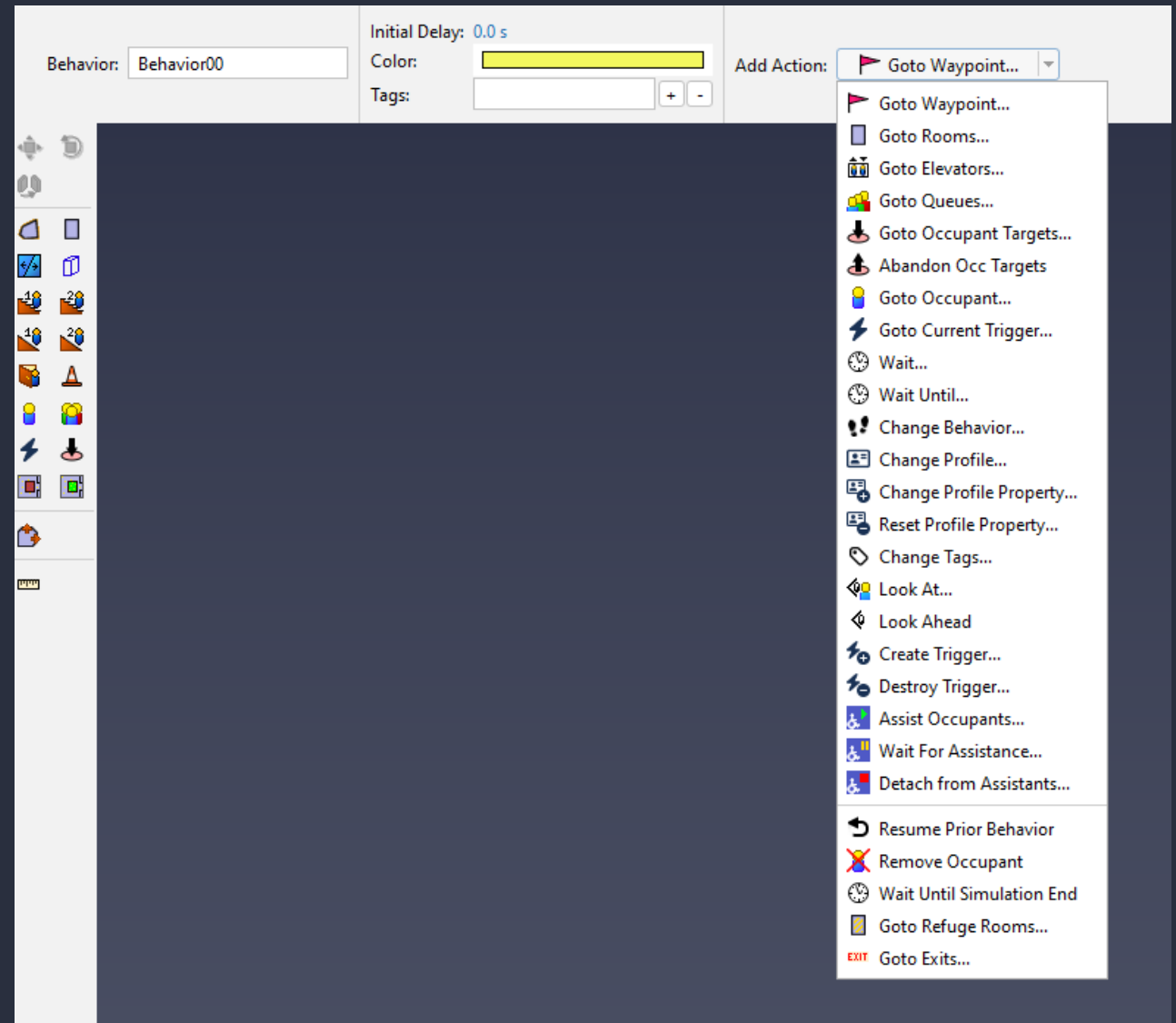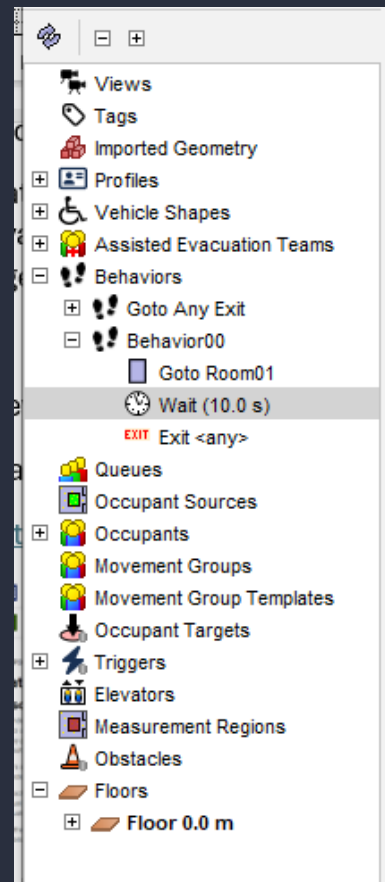
Wayfinding (Path Planning)
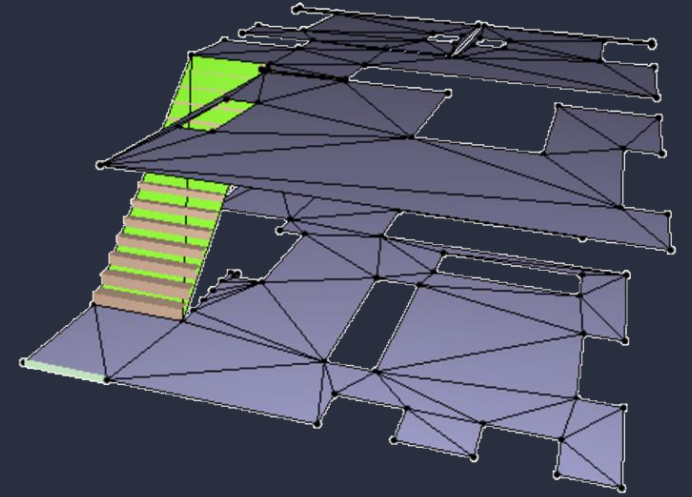
- Now that you have a goal, how do you get there

- Movement mesh
  - The basis of a model is the connected topology of rooms, walking spaces, and doors
  - All rooms and other walkable components of geometry are subdivided into a connected mesh of triangles to enable calculations

Wayfinding

- A-Star graph search is used to determine path to destination (solving a maze)

- The path is refined by string-pulling, which simplifies the path of triangle crossings into a simpler set of waypoints

- The result is the route and distance to the goal(s)

- As agents use a path, the motion followed is from a spline curve-fit
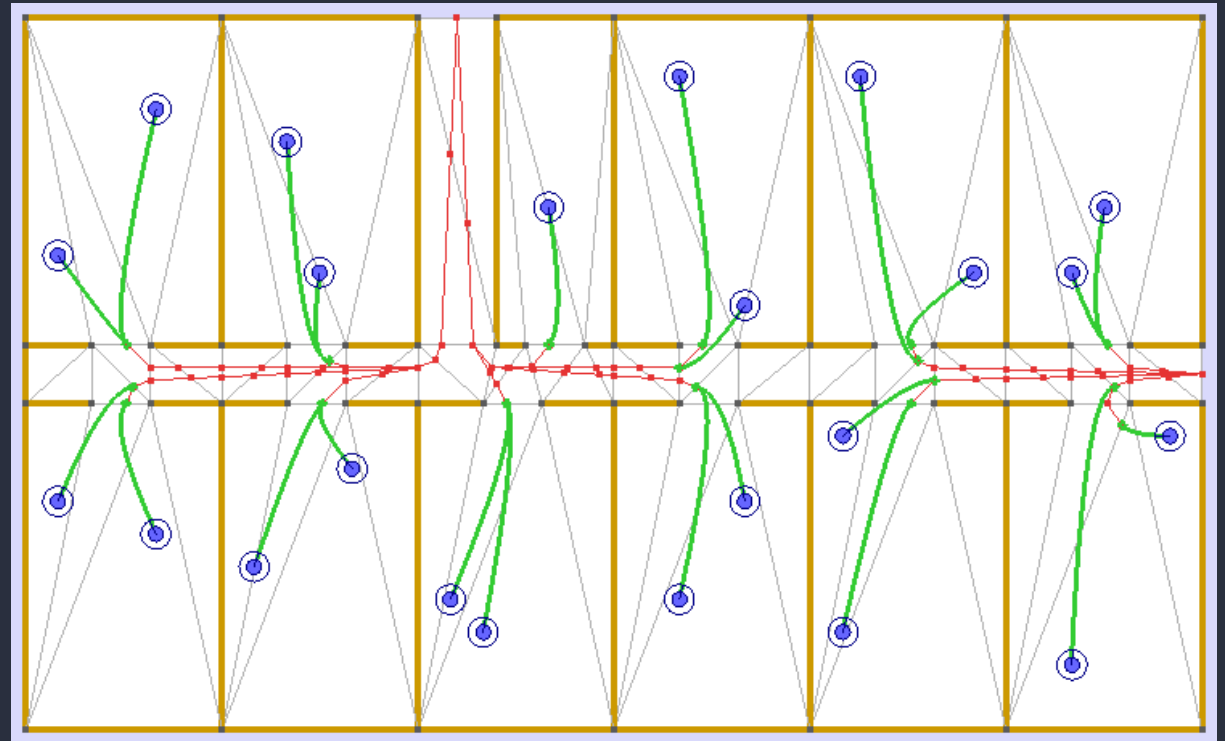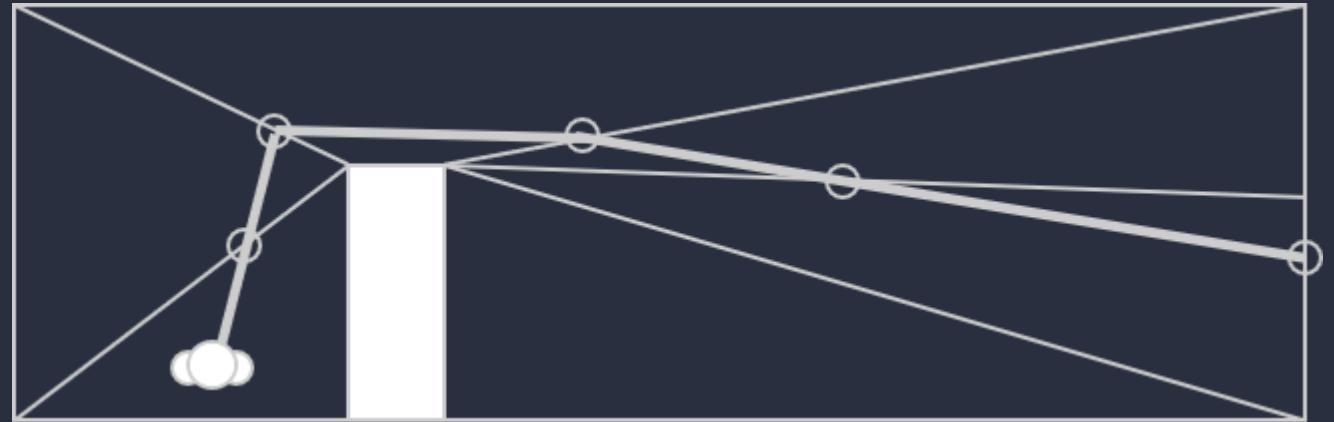
In-Room Path Planning

- Global information about the static geometry is considered known by agents – like having a memorized map of the building

- Conditions in the current room are used to refine route selection

- Locally-Quickest algorithm
  - Combine local conditions (queuing, door availability, etc.) with distance/time from each door-to-goal to pick best door
  - Can be influenced by door choice parameters in Pathfinder
  - Only the local conditions are considered – far away crowding or delays are not considered until an occupant reaches that room and becomes aware

Door Choice Parameters

Name: Profile00

Description:

Tags:

3D Model: BMan0001, BMan0002, BMan0003, BMan0012, BWom0001, BWom0002, BWom0011, CMan0001, CM

Color:

Characteristics	Movement	Restrictions	Door Choice	Animation	Output	Advanced

Cost Factors

Current Room Travel Time:	Constant	1.0
Current Room Queue Time:	Constant	1.0
Global Travel Time:	Constant	1.0
Elevator Wait Time:	Constant	0.0 s

Advanced

Current Door Preference:	Constant	35.0 %
Current Room Distance Penalty:	Constant	35.0 m

Movement (Getting Around)

- Movement Basics
  - Spline fit – a smooth,curved path to follow the route waypoints
  - Locomotion – acceleration, velocity, turning rate
- SFPE Mode
  - Original pre-Pathfinder approach – automate speed/distance/time/flowrate calculations based on SFPE handbook calculations
- Dealing with crowds – Steering Mode
  - Inverse steering – Evaluation of costs for a set of directional choices
  - Cost sub-models – idle, avoid occupants, wall collisions, density (speed), passing, cornering
  - Handling conflicts – priority, squeezing
  - Special cases – backtracking, cycle prevention

Debug Mode

- View parameters controlling occupant movement
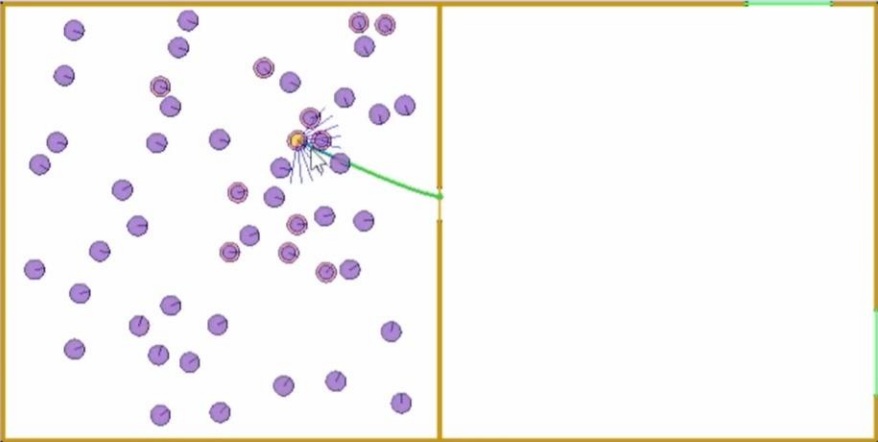- Understand errors or non-movement conditions

Debug

Rotate | Trace to Dest | Trace Crossings | Trace Obstructed

Mesh: Verts | Tris | Animate | Traversable Edges | Trimmed Edges | Color by Flags | Occ Colors: Occupants | Priority | Full Path | Groups | Counterflow | Display Orient | Social Dist | Sel. Social Dist

Nodes: Sub-mesh | Door Dists | All Door Dists | Occ Source: Segments | Occ Targets: Visible | Priority Triggers: Visible | Influence | Occ Paths: Debug

Path Debug: Reset | << | >> | z | Animate Delay: 1.0 ms | Skip: 1

Name: 00015

Navigate mesh | Locally quickest | Lane behavior | Vehicle agent | Assisted Evac Client | Calculated

Occupant | Global | Param | Nodes | Elevators

Property	Value
accelFactor	0.9090909
allowedAttractors	AlwaysTrue
animTagsIdling	[default, upright]
animTagsMoving	[default, upright]
attractorSuscIdle	0.05
attractorSuscSeek	0.01
avatar	md5/CWom0018/CWom0018.bea
behavior	Goto Any Exit: [inferno.data2.ai.ChangeTagGoal@37efe6e9, inferno.data2.ai...
behaviorStack	[inferno.sim.BehaviorSim$BehaviorInProgress@d8246f7]
bodyShape	CylinderShape: radius=0.227900, geomRadius=0.227900, height=1.82880
boundaryLayer	0.15
canMove	true
collisionResponseTime	1.5
comfortDist	0.08
compRestrictions	inferno.sim.OccProfileSim$CompRestrictions@1
curNode	Floor 0.0 m->Room00
currDoorFactor	0.65
d_finished	false
dbgProps	{LANE_BEHAVIOR=inferno.sim.steering.inverse.LaneBehavior@2078b19c, N...
decelFactor	2.0
displayLoc	(6.741880826894127, 6.860039199589937, 0.0)
displayOrient	(0.751506, -0.659727, 0.0)
distTravelledFactor	0.019804
doorQueue	
dynamicCompRestrictions	
elevatorWaitTime	[rem: 0.0 s, max: 0.0 s]
formationLeader	
fundamental	inferno.data2.value.PiecewiseFunction1d@910f7f8
id	14
initLoc	(6.697368544102859, 6.909954893901684, 0.0)
isCollidable	true
isGroupLeader	false
isPassive	false
loc	(6.741881, 6.860039, 0.0)
localQueueTimeFactor	1.0

Cursor position
x: 7.03555
y: 6.69911

View
Reset View

Control simulation
|| | Step | Delay (ms): 100 | Sim Time (s): 0.4 | Pause at this time | 0.0

Select occupant
Select | occupant's name or id

Debug

Mesh: Verts Tris Animate Traversable Edges Trimmed Edges Color by Flags Occ Colors: Occupants Priority Full Path Groups Counterflow Display Orient Social Dist Sel. Social Dist

Nodes: Sub-mesh Door Dists All Door Dists Occ Source: Segments Occ Targets: Visible Priority Triggers: Visible Influence Occ Paths: Debug

Path Debug: Reset << >> z Animate Delay: 1.0 ms Skip: 1

Name: 00015

| Occupant | Global | Param | Nodes | Elevators |
| Navigate mesh | Locally quickest | Lane behavior | Vehicle agent | Assisted Evac Client | Calculated |

Showing results for: 00015

local target	global target	local dist	global dist	total dist	local time	global time	total time
Floor 0.0 m->Do...	[Door01, Door02]	7.106871	0.0	7.106871	6.350948 (q: 0.37...	0.0	6.350948
Floor 0.0 m->D...	[Door01, Door02]	3.080927	0.0	3.080927	3.175378 (q: 1.1...	0.0	3.175378

Doors comparison

	Floor 0.0 m->Door01	Floor 0.0 m->Door02
Floor 0.0 m->Door01		1
Floor 0.0 m->Door02	-1	

Cursor position
x: 227.953027
y: 161.041069

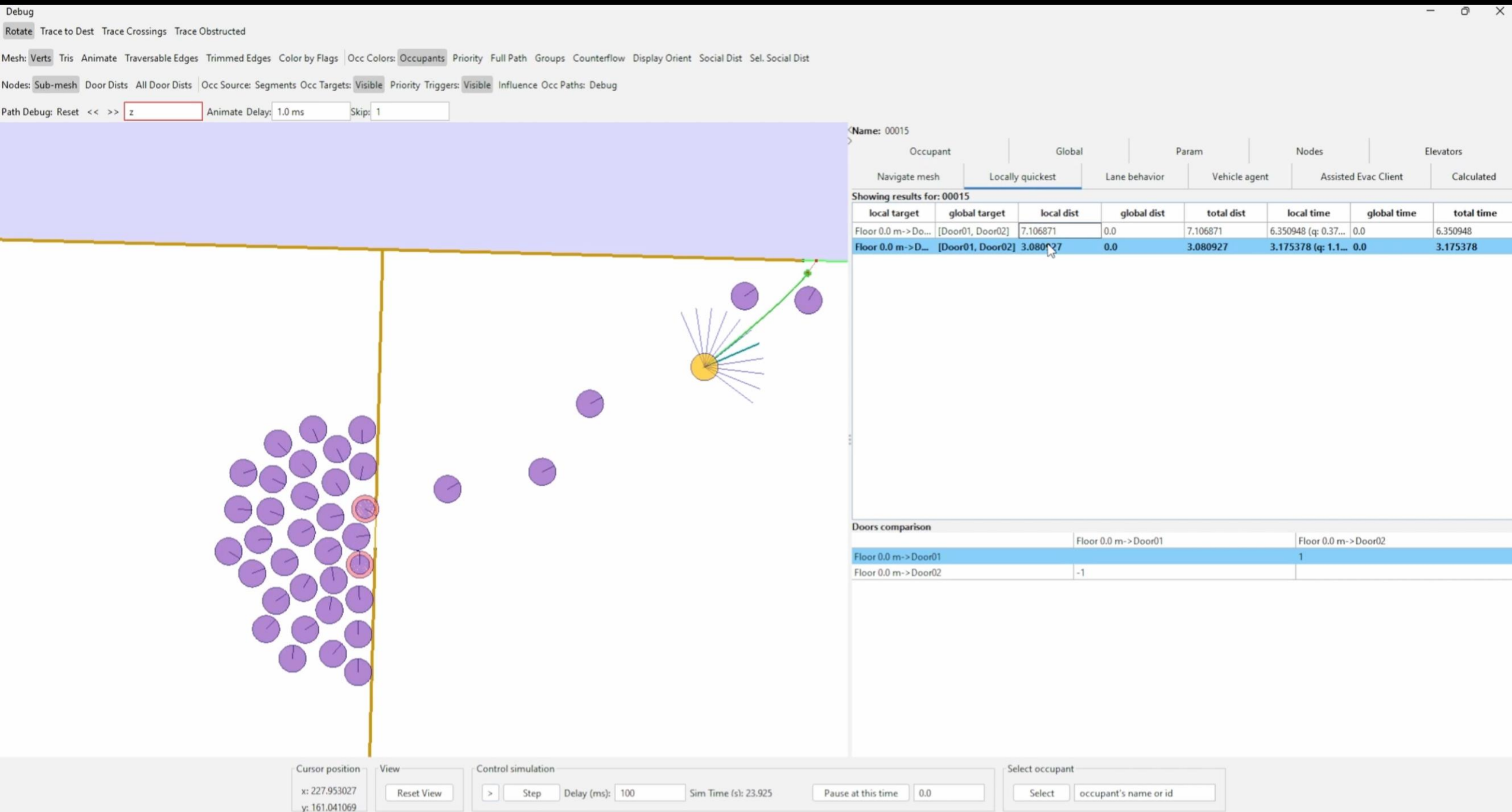View
Reset View

Control simulation
> Step Delay (ms): 100 Sim Time (s): 23.925 Pause at this time 0.0

Select occupant
Select occupant's name or id

More Movement Information

- See the User Manual and Technical Reference for more information on:
    - Vehicles
    - Grouping
    - Assistance
    - Elevators

Extending Behaviors

- Change Behavior action

- 2021 – New Features
  - Attractors – regions that can change behavior
  - Occupant Targets – model seating and other interior destinations

- 2023 – Worked with GHD / Movement Strategies to model complex, dynamic events
  - Generalized Attractors into Triggers
  - Moving Triggers
  - Creation/Deletion of Triggers
  - New Behavior Actions – override profiles, tagging, etc.

Target Behaviors

%	Target Behaviors
0.0	No Change
0.0	Behavior00
100.0	Goto Any Exit

Total distribution: 100.0%

Clear...   Distribute Evenly...

☐ Display only non-zero rows
☐ Show group labels

Create   Cancel

0.0

What is a Trigger

- A Trigger changes the behavior object of an occupant
    - The Behavior describes the *what*
    - The Trigger describes the *when*
- Can indirectly cause change to anything a behavior action can modify
    - Goals (seek/idle/immediate)
    - Profile (speed, attributes)
    - Tagging
- Triggering can be based on time and/or location, and can include probabilities

Trigger-Occupant Interaction

Rank: `0`
Behavior: 👣 `<Wait at Trigger>`
☐ Resume if interrupted

Wait Area Radius: `1.0 m`
Wait Time: 60.0 s

Allowed Occupants: Accept All
Decision Time: `Automatic`
☐ Remain aware

Awareness: `Line of Sight`
Awareness Radius: `2.0 m`
Awareness Requirements: Count ≥ 1, Time ≥ 0.0 s

Influence: Always 100.0 %
Influence Timeline: `Trigger`
☐ Ignore Occupant Susceptibility

- Awareness

- Influence

- Susceptibility

- Tags

Awareness

- Location / Radius
- Room of Trigger
- Set of Rooms
- Global

Awareness:	Line of Sight ▾
Awareness Radius:	Line of Sight
Awareness Requirements:	Same Room
	Specified Rooms
	Global

Trigger = <Turn Red>

Exited: 0 /0

Awareness = Radius

Awareness = Same Room

Awareness = Specified Rooms ^
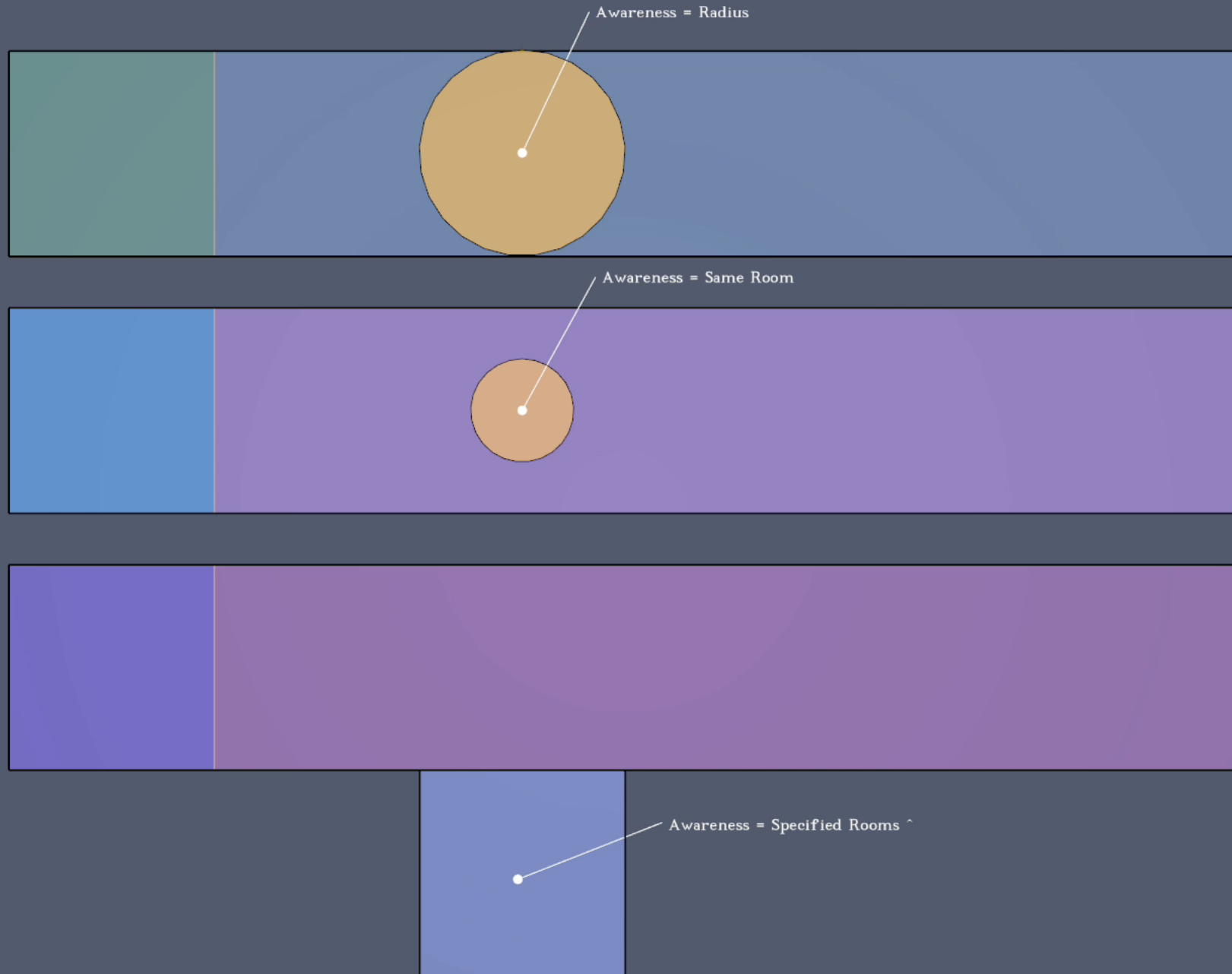
Awareness: Line of Sight
Awareness Radius: 1.0 m
Awareness Requirements: Count ≥ 1, Time ≥ 0.0 s

Awareness Requirements

Min. Awareness Count: 3

Min. Awareness Time: 0.0 s

OK   Cancel
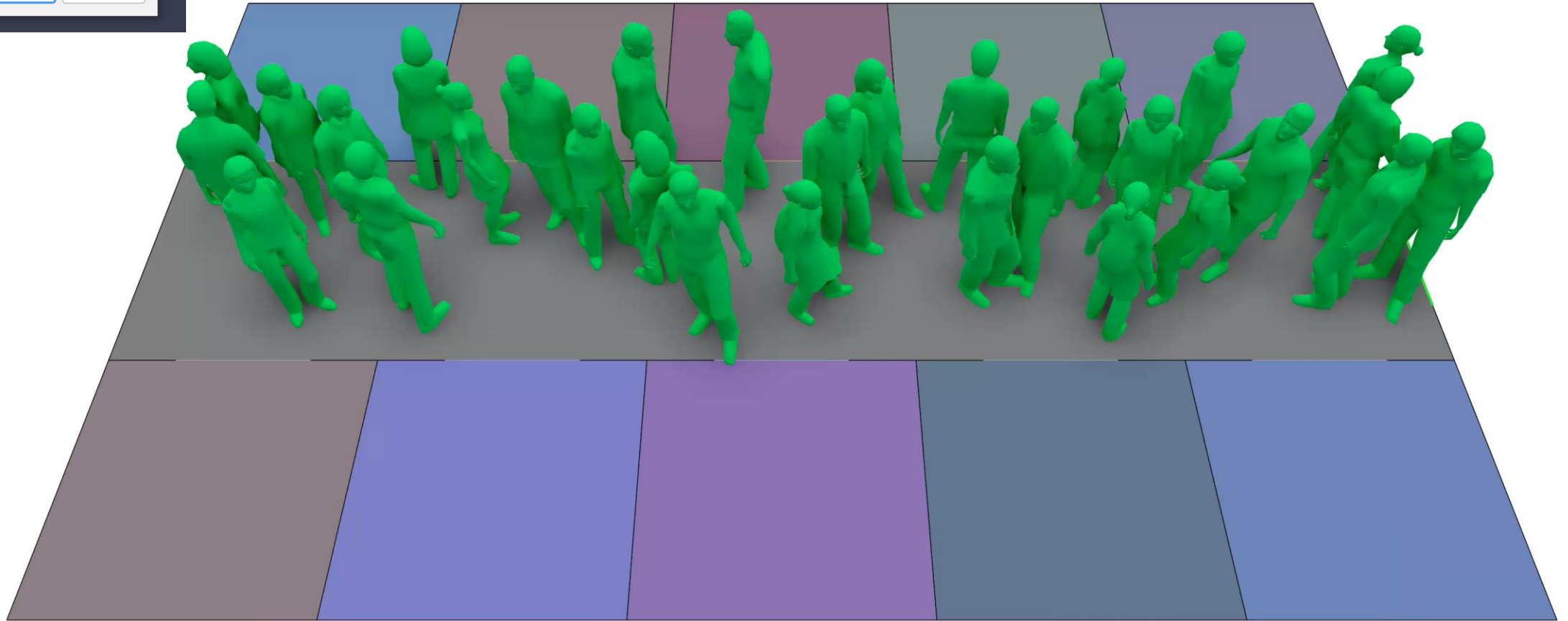
Influence

- When the trigger is effective
- How likely the trigger is to change behavior
- Timing can be relative to the creation time of the trigger or to the global timeline

Influence: __Always 100.0 %__

Influence Timeline: Trigger ▾

☐ Ignore Occupant Susceptibility

Edit Influence ✕

Initial Value: 100.0 %

Timed Values

	Time	Value
*		

- Insert Row
- Remove Row
- Move Up
- Move Down
- Copy
- Paste
- Cut

OK   Cancel

Susceptibility

- How likely the **occupant** is to respond to a trigger

- Adds flexibility for finer-grained combinations

- Total probability P = I x S

- Can be overridden by Trigger (Ignore Occupant Susceptibility)

Name:	Profile00
Description:	
Tags:	

3D Model: BMan0001, BMan0002, BMan0003, BMan0012, BWom0001, BWom0002, BWom0011, CMan0001, CM

Color:

Characteristics	Movement	Restrictions	Door Choice	Animation	Output	Advanced

Initial Orientation: Uniform [0.0 °, 360.0 °] Edit...

☐ Requires Assistance to Move

☐ Ignore One-way Door Restrictions

Escalator Preference: Stand anywhere

Trigger Susceptibility (Seeking): Constant 1.0 %

Trigger Susceptibility (Waiting): Constant 5.0 %

Allowed Triggers: Accept All

Susceptibility = 25%   Influence = 100%

Susceptibility = 50%   Influence = 100%

Susceptibility = 25%   Influence = 50%

Susceptibility = 25%   Ignore Susceptibility ON
Influence = 100%

Susceptibility = 25%   Ignore Susceptibility ON
Influence t(0) = 0%, t(50) = 100%
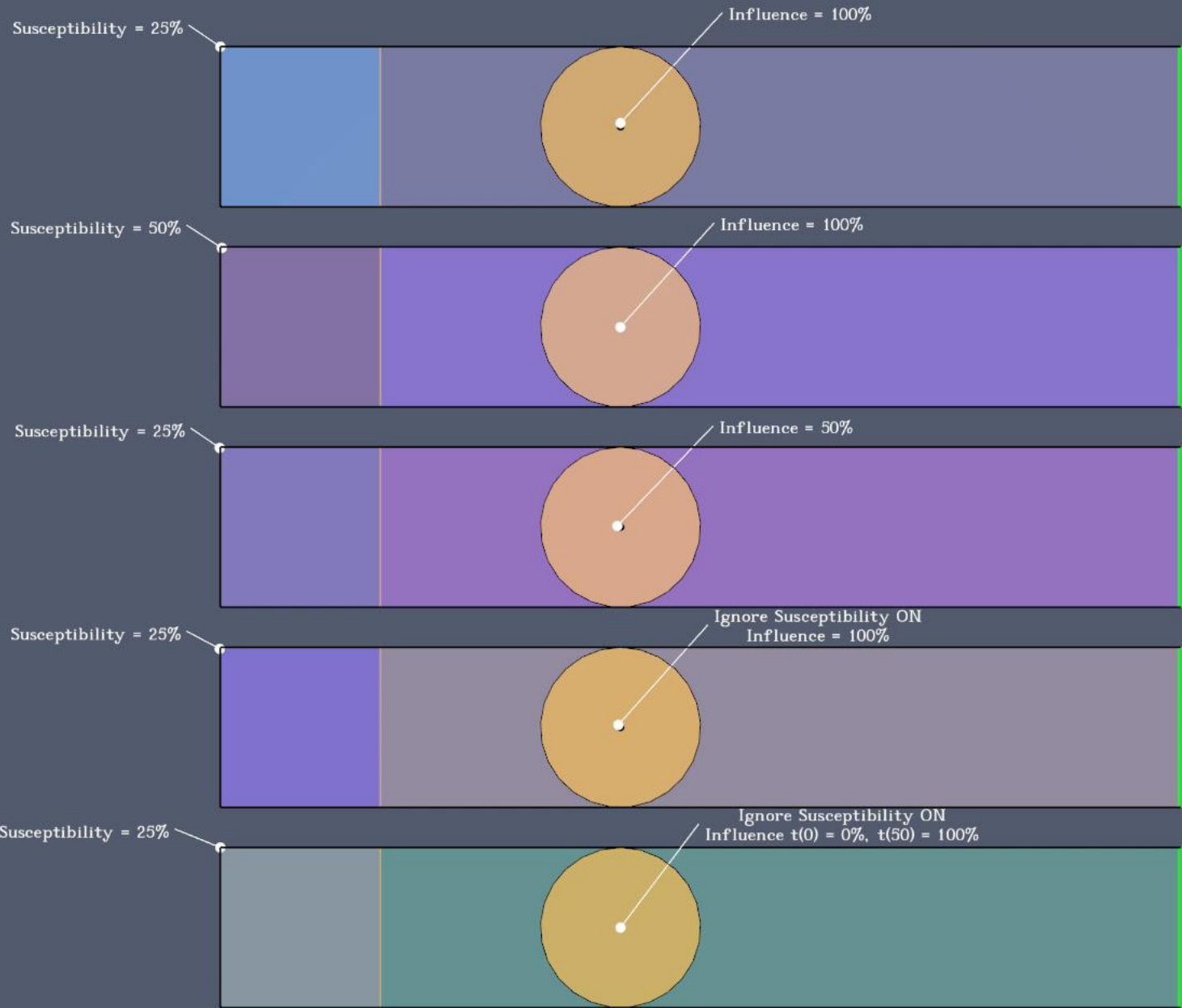
Tags

- Useful for organization-search-rename

- Can filter the awareness of a trigger

- Allows trigger to only affect specifically tagged (or un-tagged) occupants

- Combined with the Change Tags behavior action, complex state-based changes are possible

- Can be used for single action, or to chain subsequent triggers

Trigger = <Turn Red>

Accept Green

Reject Green

Influence = 50%

Accept Red

Trigger = <Turn Yellow>

Trigger Rank

- If more than one trigger is valid
  - More than one applicable
  - A new trigger available during previous trigger

- Rank controls which trigger is used for the time step
  - Higher rank = more precedence

Rank: 0

Behavior: 👣 <Wait at Trigger> ⌄

☐ Resume if interrupted

- Occupants enter and look around and use the restroom due to low-rank triggers.
- At t=150 two global triggers with a higher rank activate.
    1) 25% of occupants delay briefly then exit.   2) 25% of occupants wait for some time then exit.
- At t=200, a higher-rank global trigger activates directing 50% of occupants to exit.
- At t=250, a final higher-rank global trigger activates directing 100% of occupants to exit.
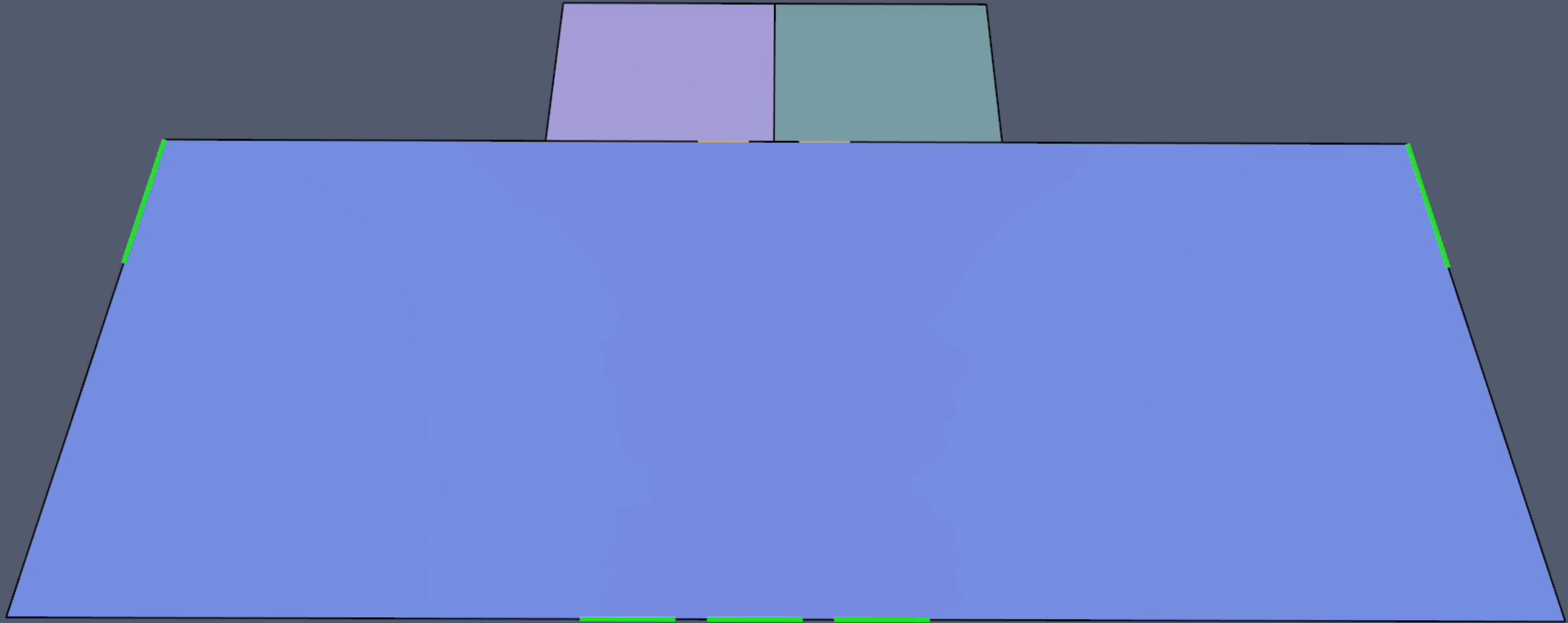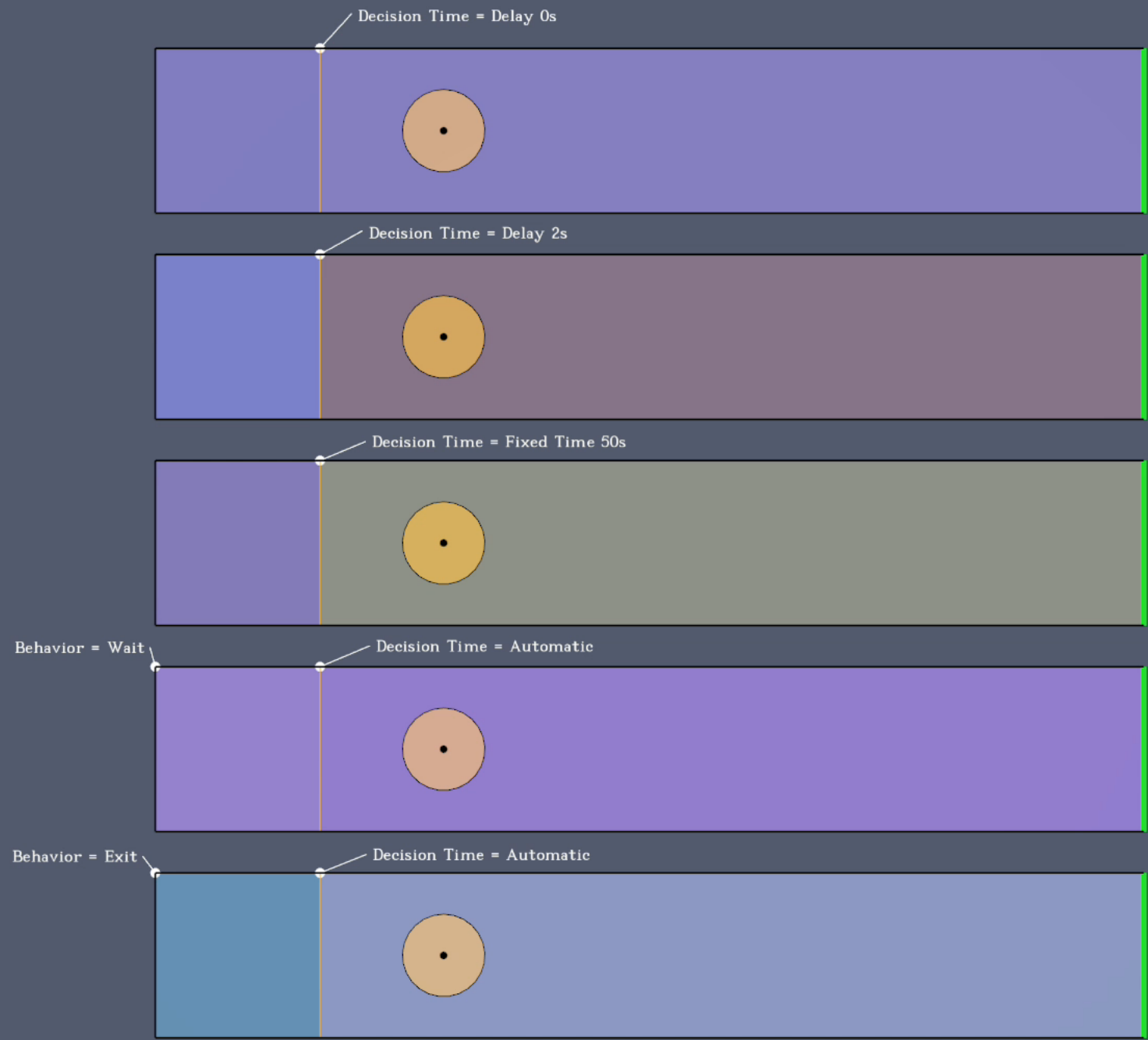
Stacked Triggers and Behavior

Goto Waypoint...

⚑	Goto Waypoint...
▥	Goto Rooms...
⛉	Goto Elevators...
⛻	Goto Queues...
⚓	Goto Occupant Targets...
⚓	Abandon Occ Targets
⚑	Goto Occupant...
⚡	Goto Current Trigger...
⏱	Wait...
⏱	Wait Until...
⁈	Change Behavior...
▣	Change Profile...
▣	Change Profile Property...
▣	Reset Profile Property...
⬙	Change Tags...
⚲	Look At...
◈	Look Ahead
⚡	Create Trigger...
⚡	Destroy Trigger...
▥	Assist Occupants...
▥	Wait For Assistance...
▥	Detach from Assistants...
↺	**Resume Prior Behavior**
✗	Remove Occupant
⏱	Wait Until Simulation End
▯	Goto Refuge Rooms...
EXIT	Goto Exits...

Decision Time

- Trigger property that controls when the trigger is considered by the occupant (after awareness)
  - Automatic, Delay, Specific Time
- Another means of adding a form of distribution or randomness to the model
- Similar to pre-movement delays

Decision Time = Delay 0s

Decision Time = Delay 2s

Decision Time = Fixed Time 50s

Behavior = Wait

Decision Time = Automatic

Behavior = Exit

Decision Time = Automatic

Dynamic and Transient Triggering

- Allows behavior influence by a moving occupant
  - Accomplished with the Create Trigger behavior action
  - Trigger Templates define the trigger properties to be used
- Allows rich and complex behavior modeling
  - Information flow – A moving occupant can have a trigger that propagates the trigger to other occupants
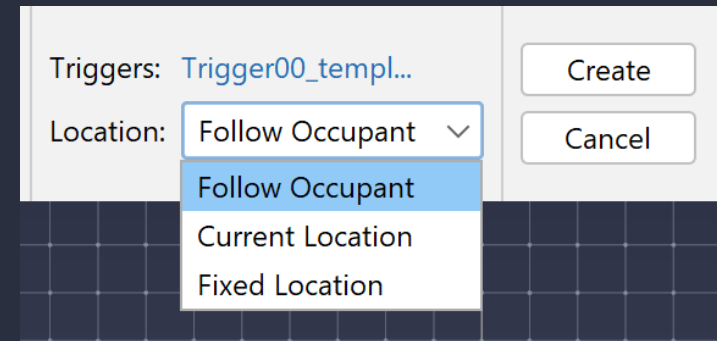
Trigger Creation Options

Follow Occupant

Current Location

Fixed Location
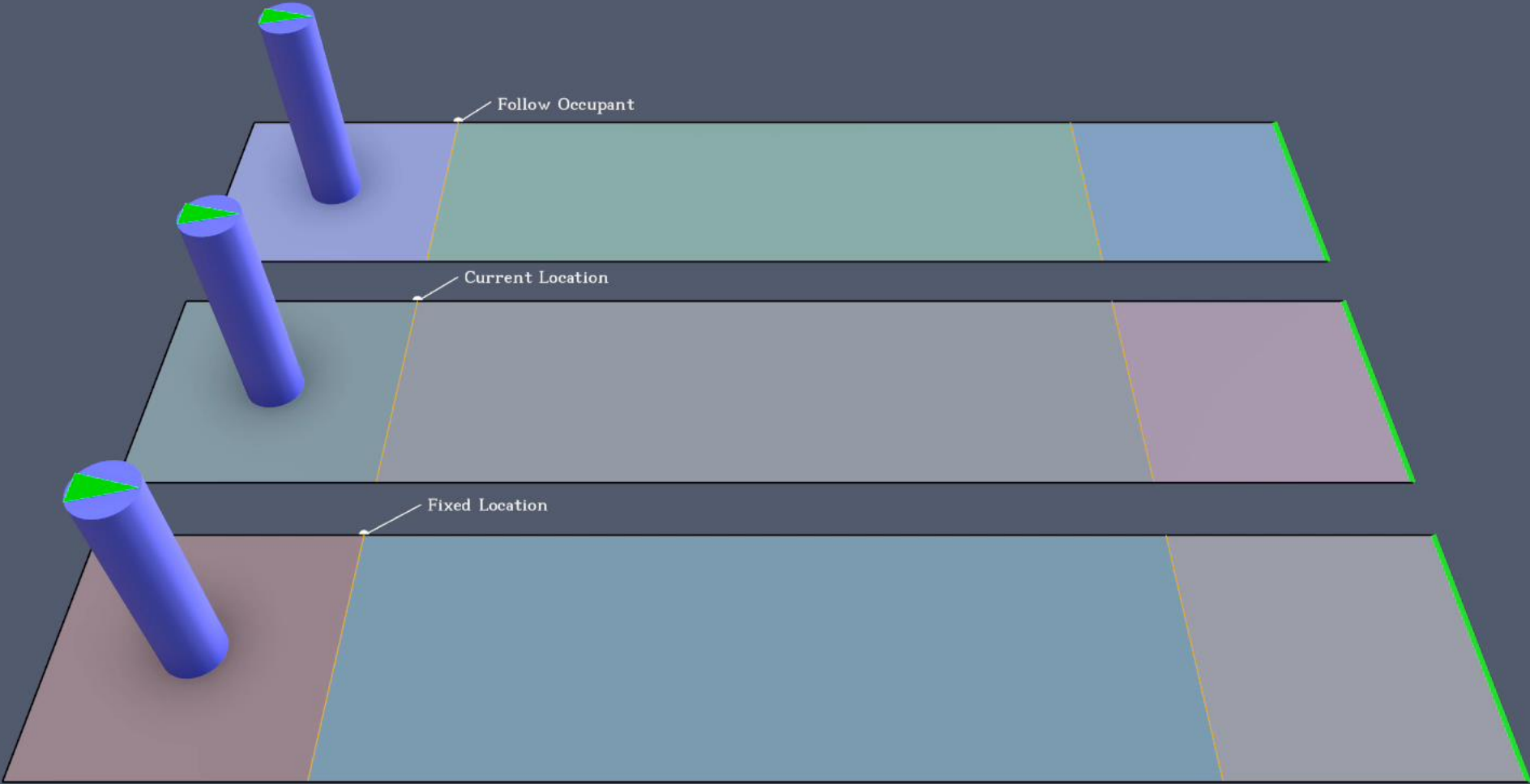
Moving Triggers
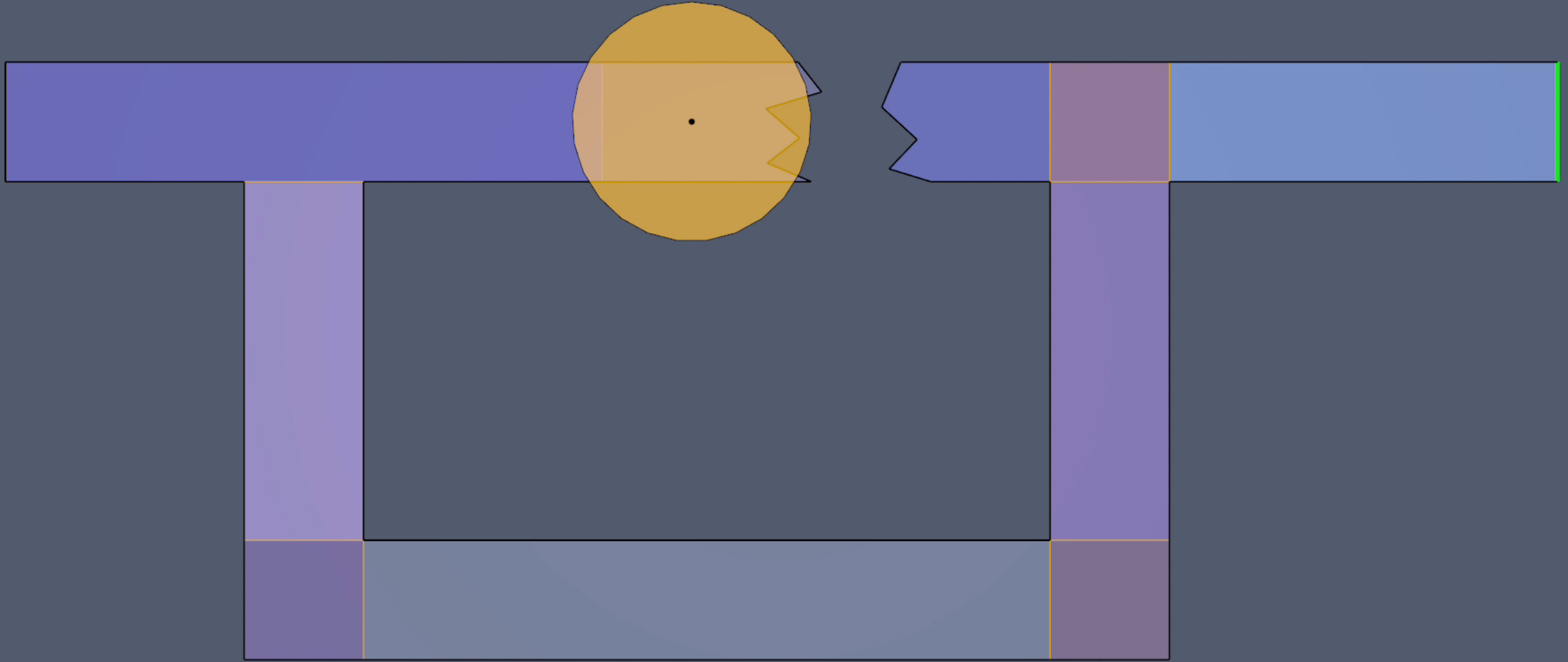
Combination / Advanced Modeling

- Social behavior
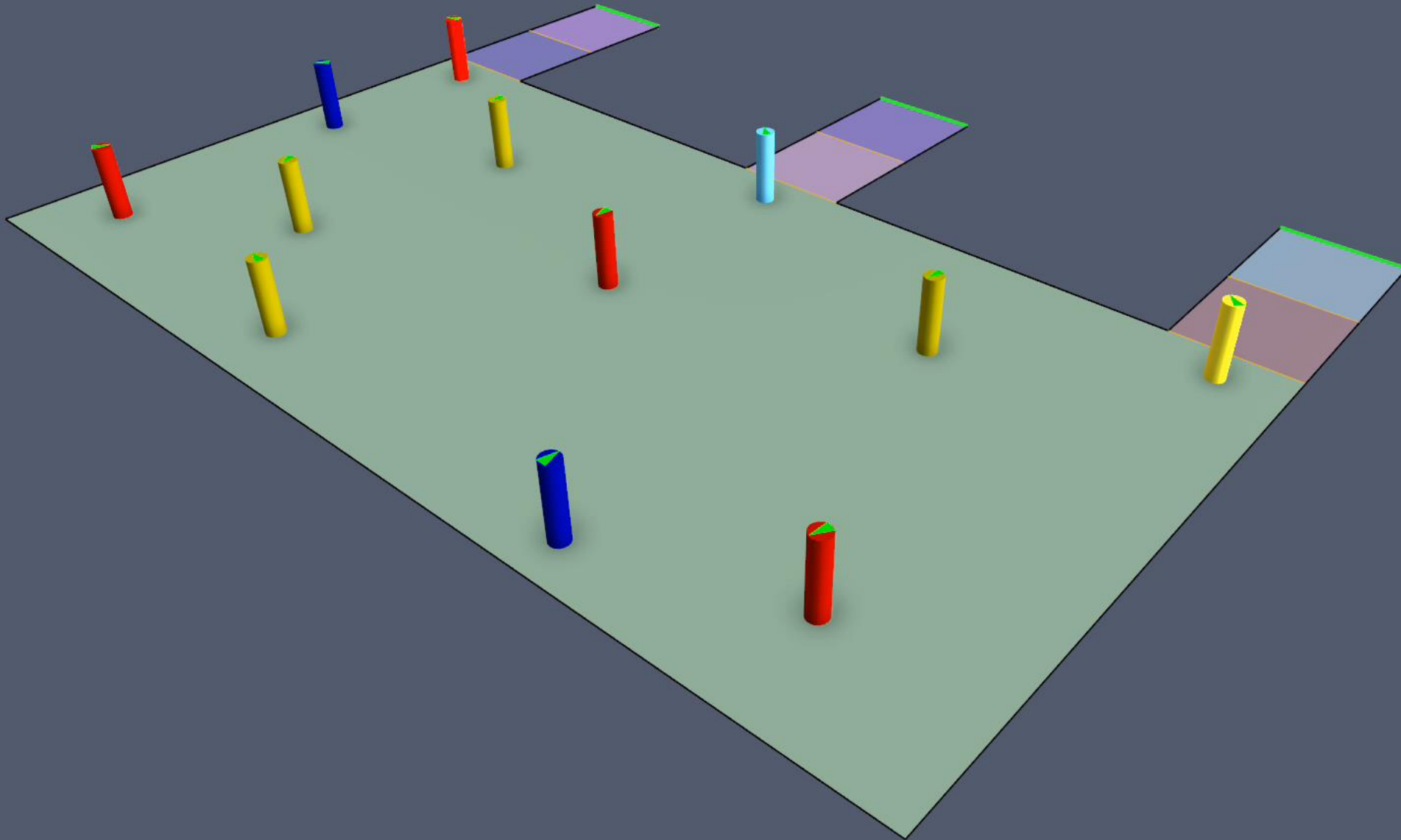
- Complex drills

- Active violence simulation

- Grouping

Combine with dynamic graphics
- Custom animations (controlled by tags)
- Swap out CAD geometry during timeline
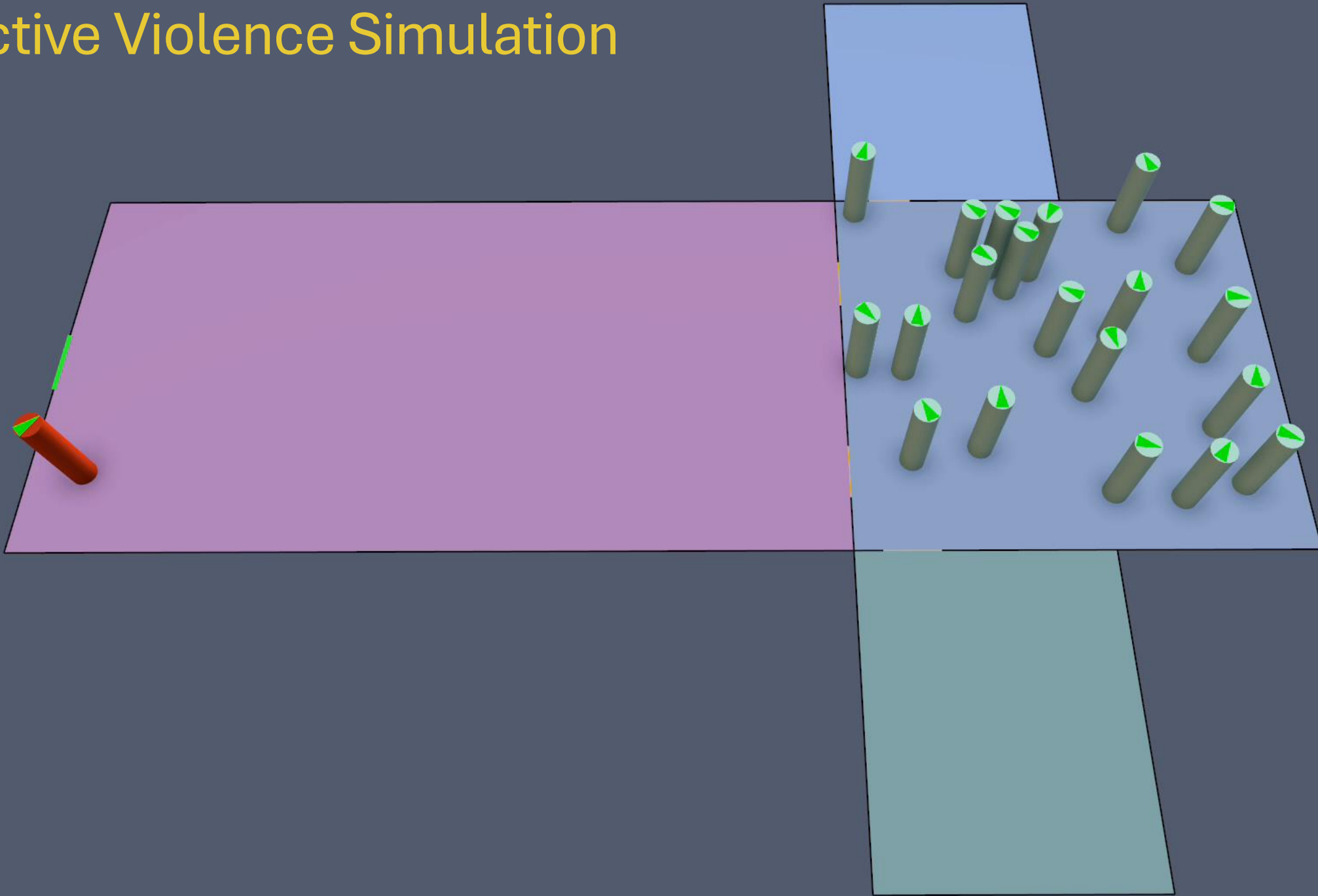
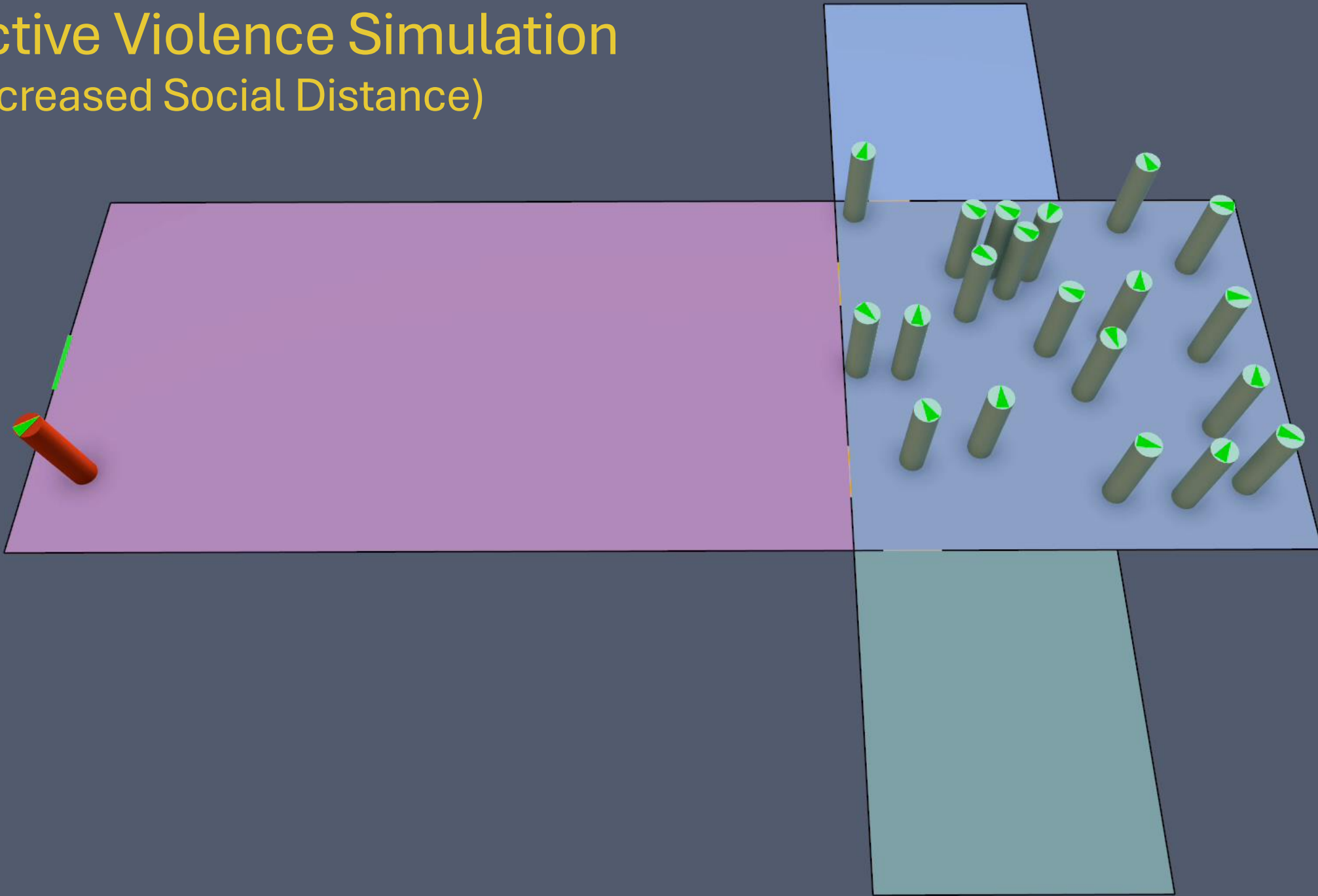Custom Animations with Triggers and Tagging

Simulated Grouping with Triggers

Active Violence Simulation

Active Violence Simulation
(Increased Social Distance)

www.thunderheadeng.com for more examples

Acknowledgements

Thank You