De mens in mensenmassa's

Het complexe samenspel van individu en collectief

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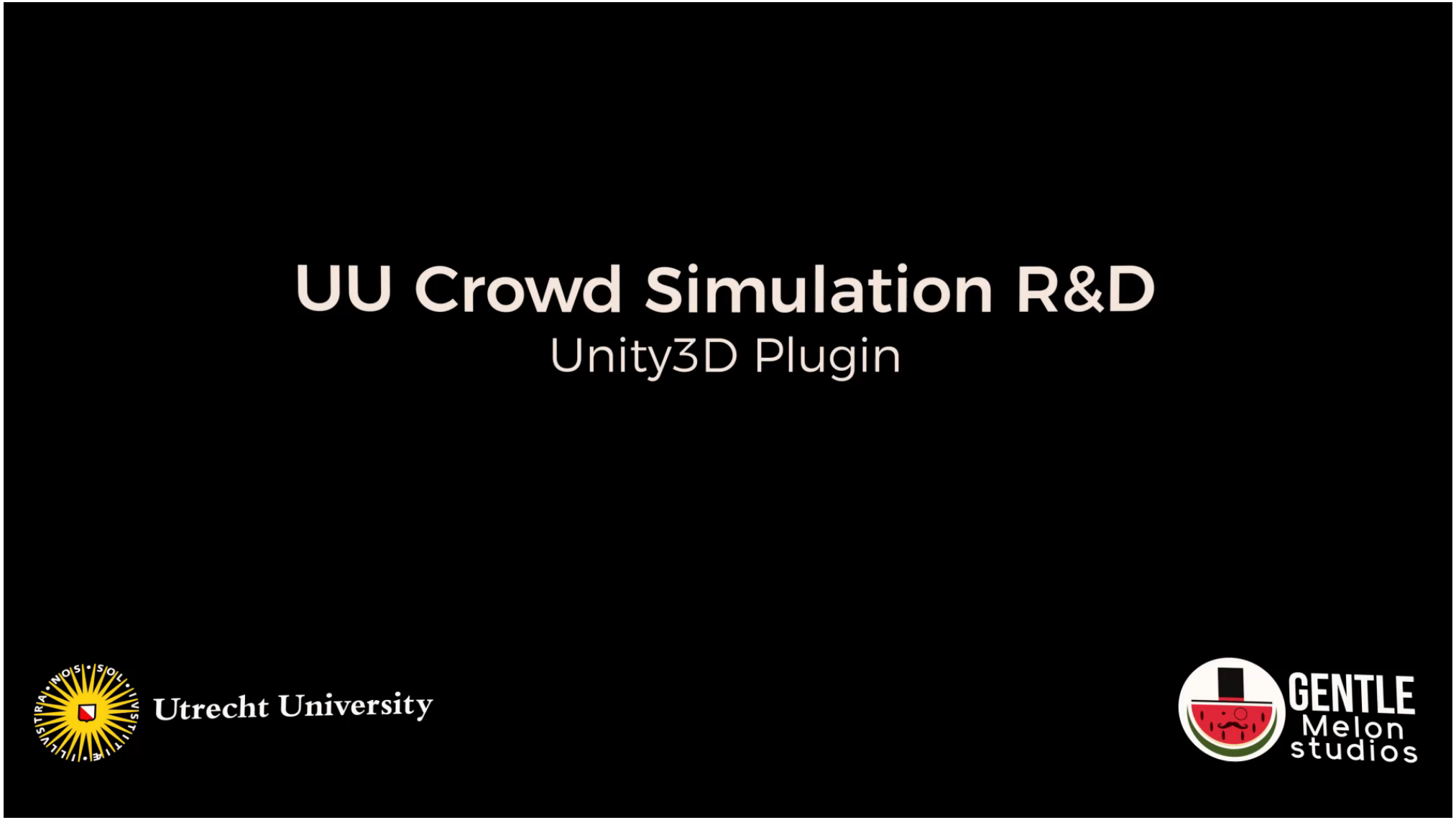
Our story

Societal relevance of simulation

- The number of environments with big crowds are growing
- Questions
  - In how much time can a train station be evacuated?
  - Where and how can potential dangerous situations appear?
  - How can a city accommodate 0.5M people during an event?
  - How can we populate a game world with a believable crowd?


Love Parade, 2010
21 deaths, 510 injuries

Real-time, interactive crowd simulation



How

can you simulate
a human crowd
interactively?

Crowd simulation framework

- Representation environment
- Level 5
  - Plans actions
- Level 4
  - Creates indicative routes
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  - E.g. to avoid collisions
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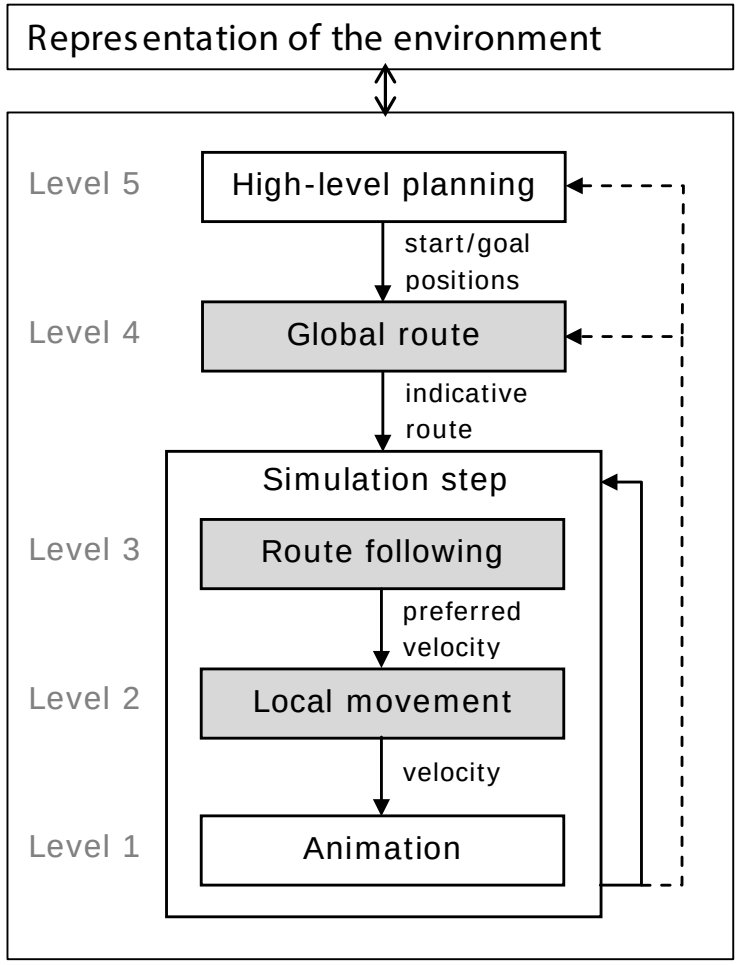
  - Moves the characters



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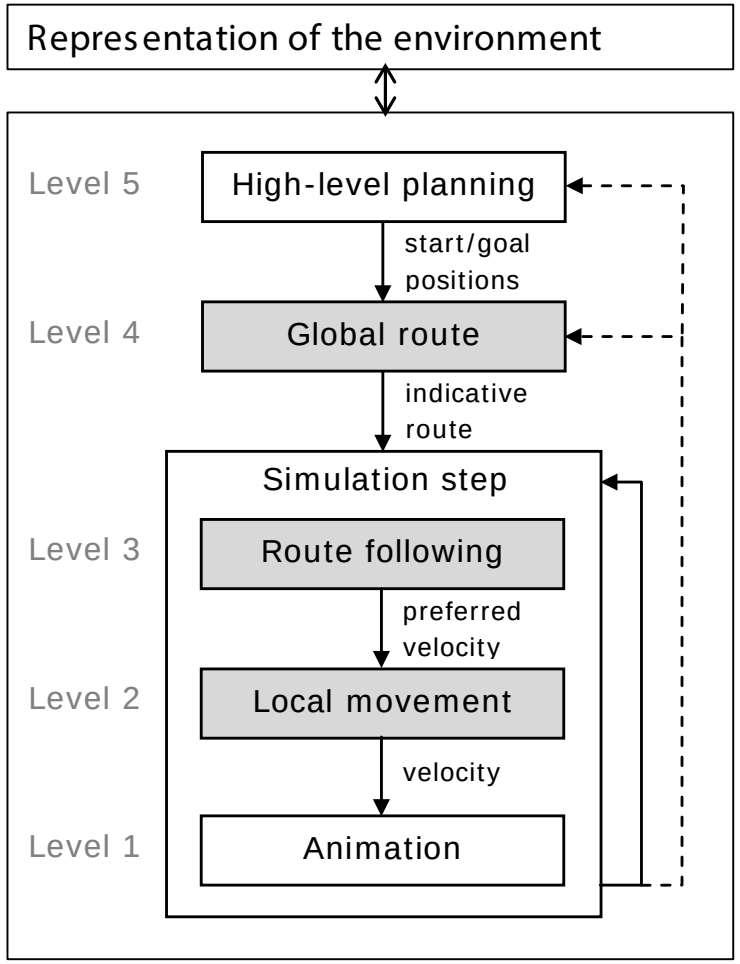
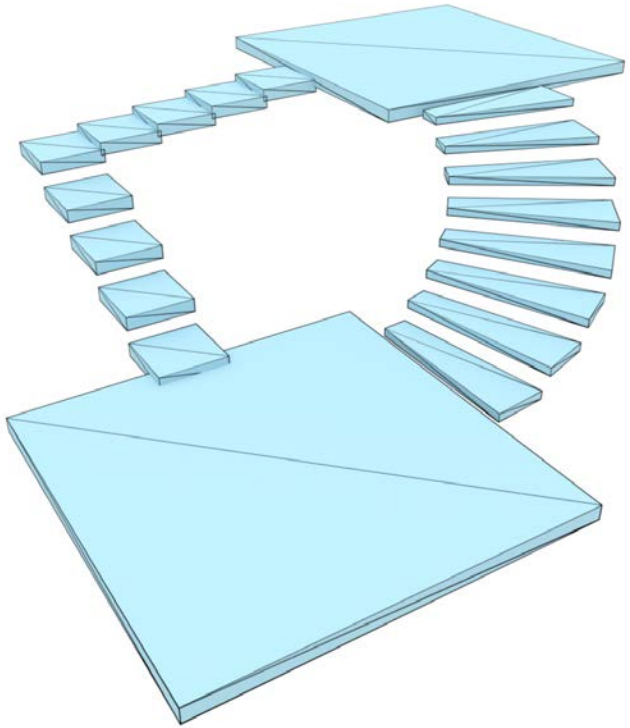


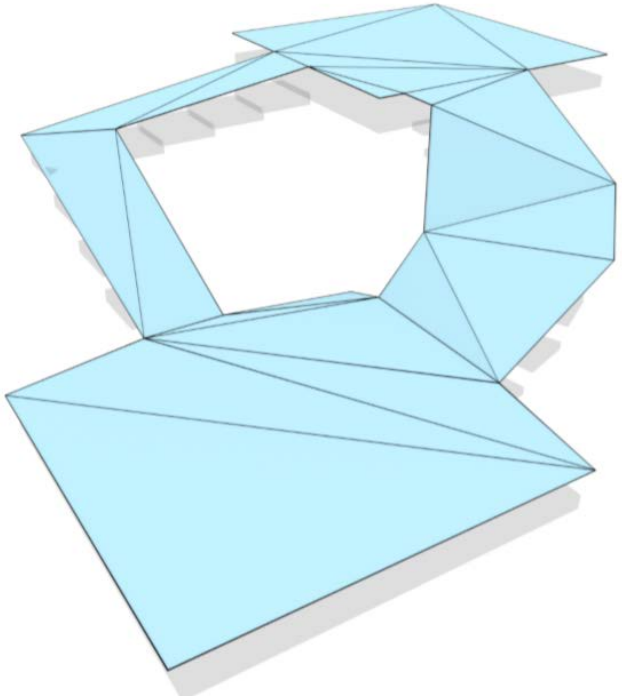
Van Toll, Jaklin, and Geraerts, 2015. Towards Believable Crowds: A Generic Multi-Level Framework for Agent Navigation.

From 3D geometry to a navigation mesh

But, this doesn't this already exist?

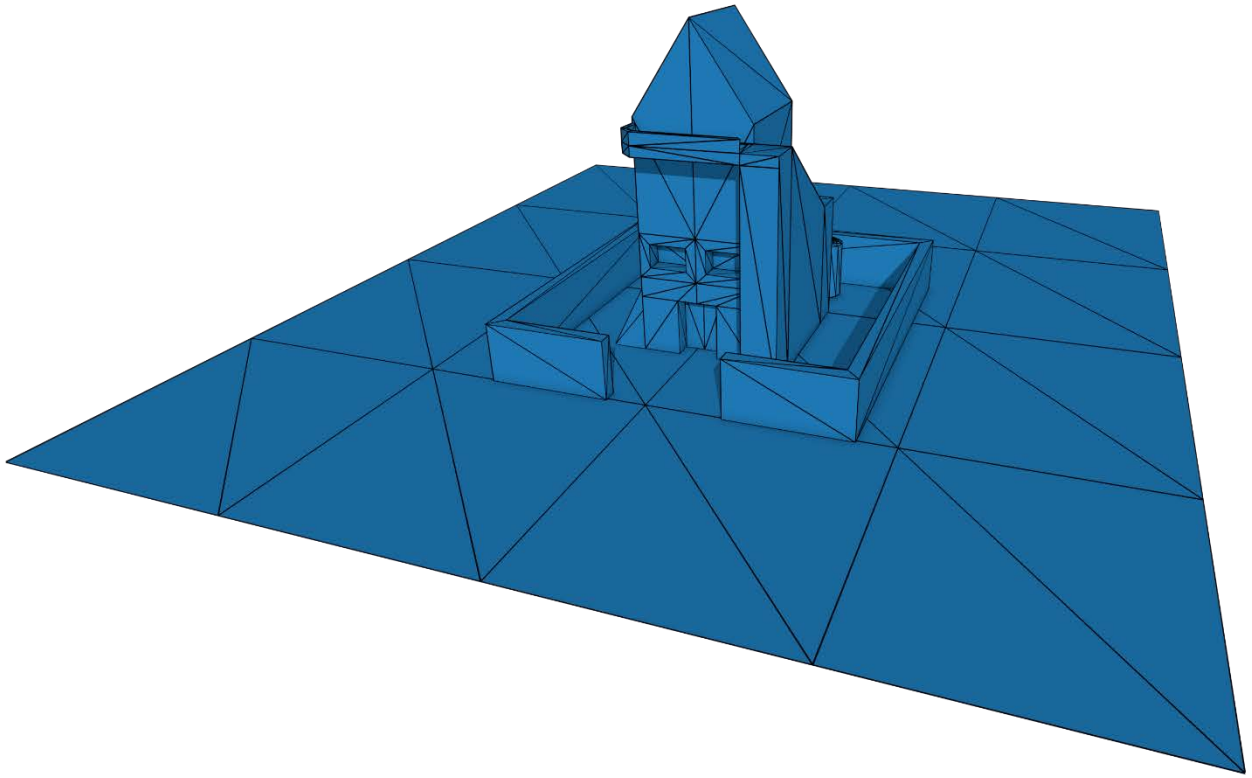
- There are standards such as BIM, CityGML,…
  - Not common practice, many geometric errors
- Current solutions make approximations and errors





From 3D geometry to navigation mesh

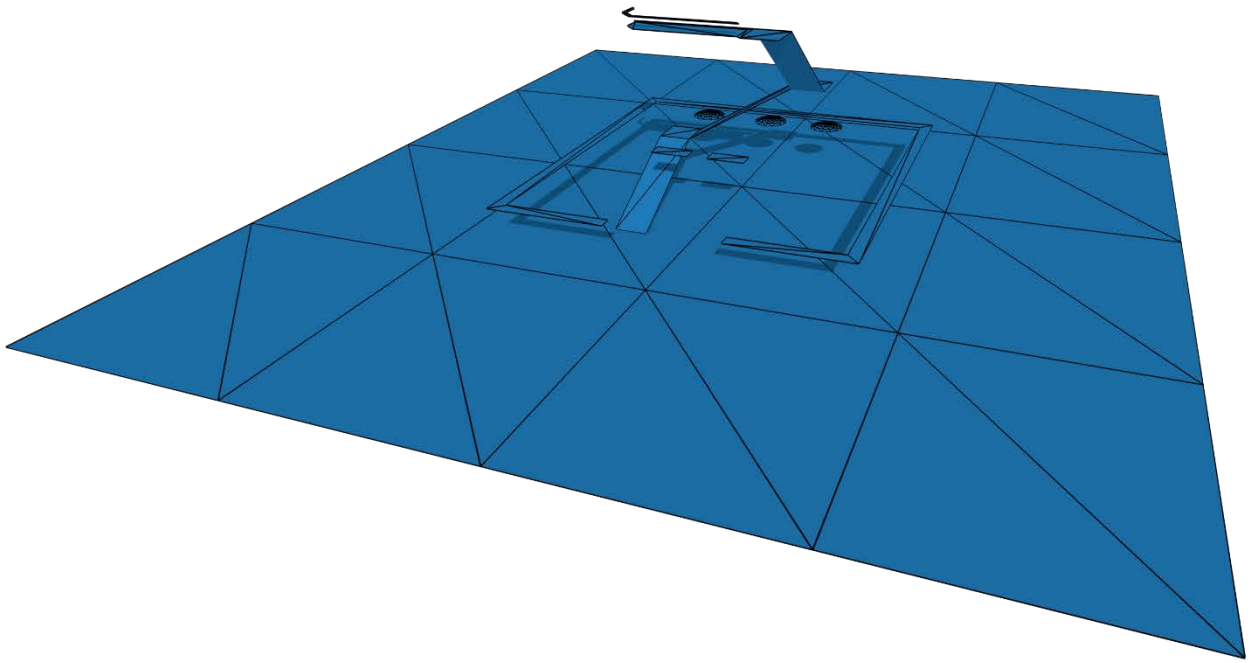
- Goal: extract the walkable areas *exactly*
  - Input environment



Hillebrand et al. Separating a Walkable Environment into Layers. In ACM SIGGRAPH Conference on Motion in Games. pp. 101-106, 2016

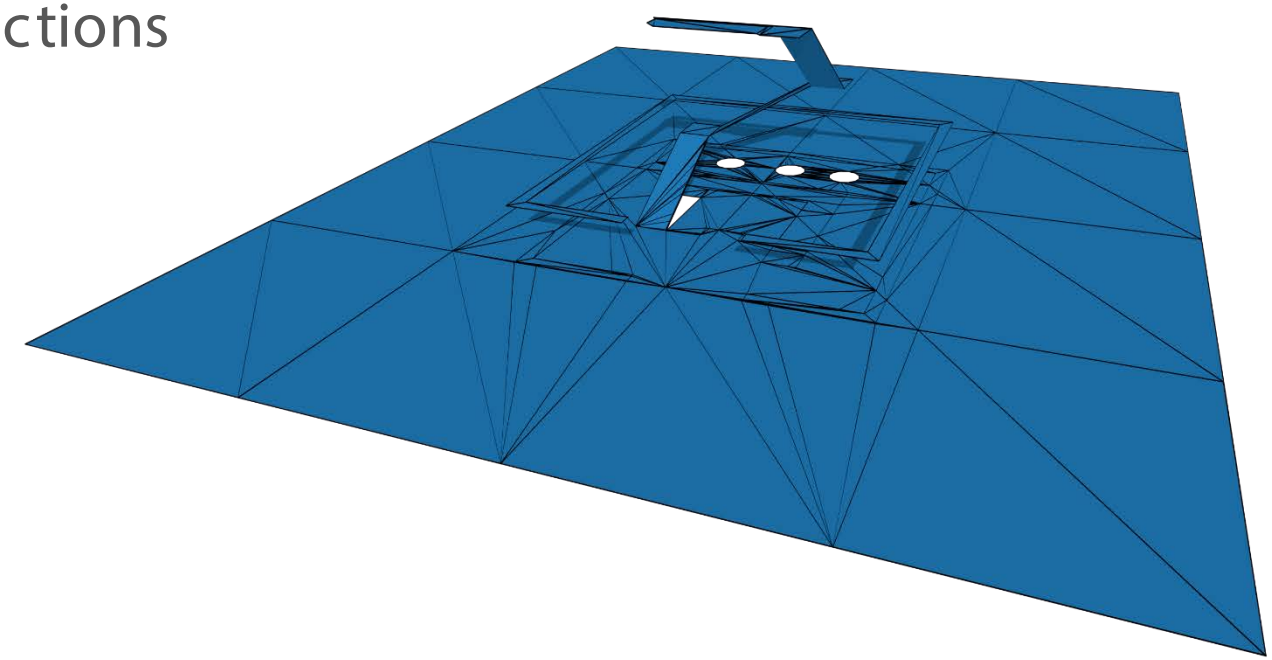
From 3D geometry to navigation mesh

- Goal: extract the walkable areas *exactly*
  - Remove (annotate) steep polygons



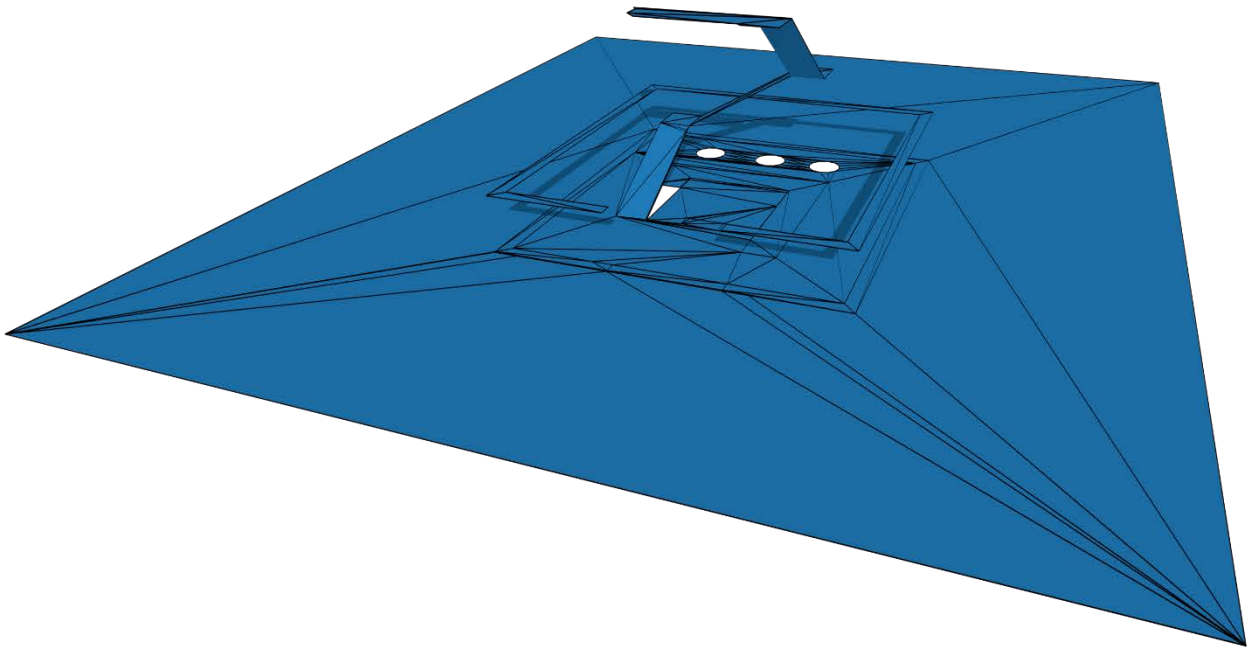
From 3D geometry to navigation mesh

- Goal: extract the walkable areas *exactly*
  - Cut out polygons giving headaches
  - Resolve degeneracies
  - Resolve intersections



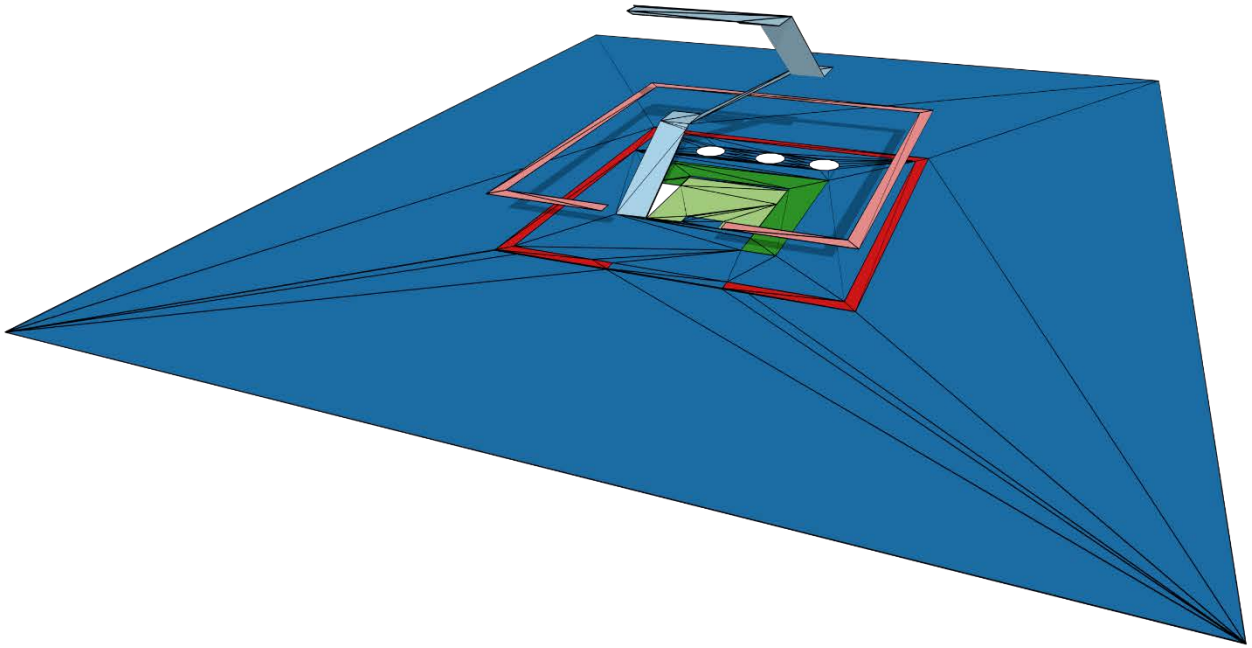
From 3D geometry to navigation mesh

- Goal: extract the walkable areas *exactly*
  - Simplify triangulations



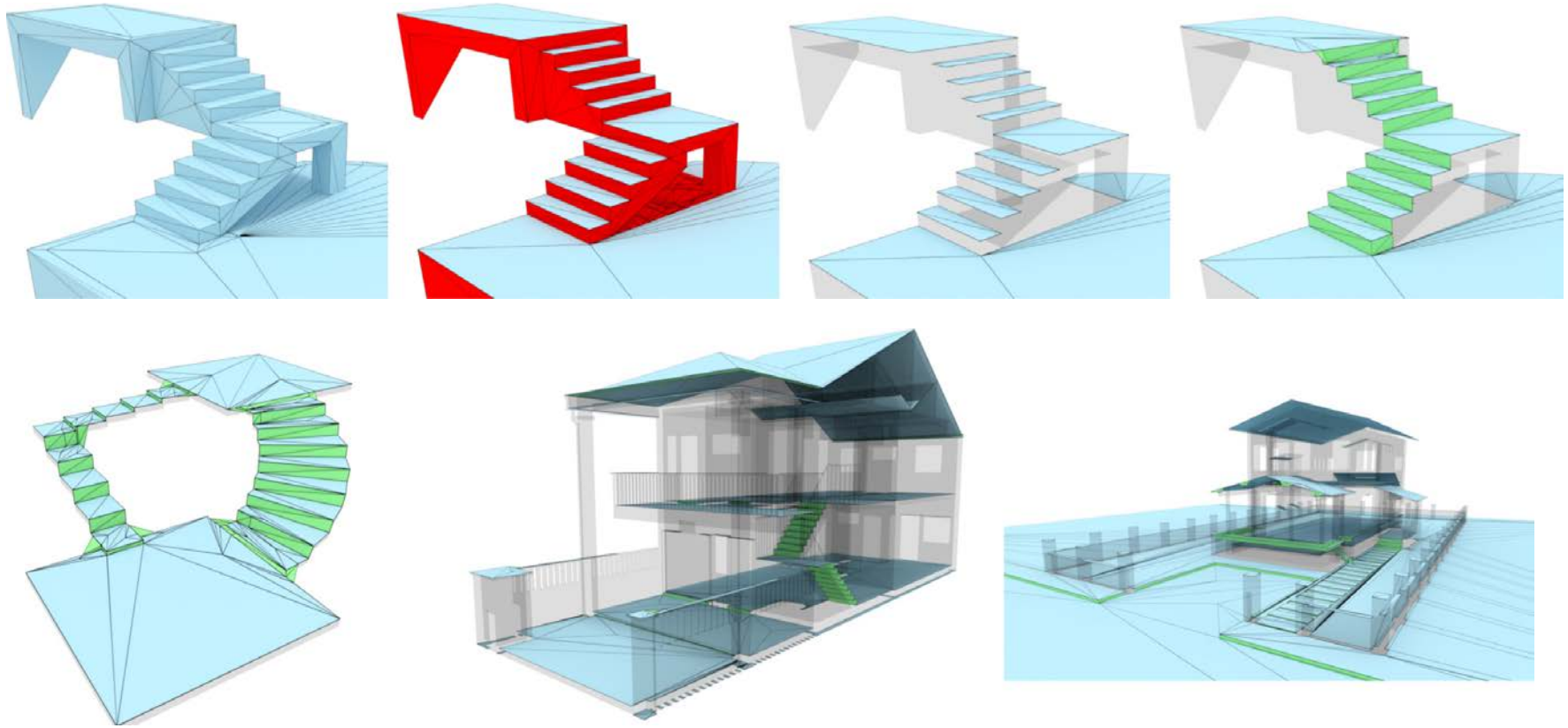
From 3D geometry to navigation mesh

- Goal: extract the walkable areas *exactly*
  - Separate into 2D (projectable) layers



From 3D geometry to navigation mesh

- Goal: extract the walkable areas *exactly*
  - Resolve gaps



J.L. Vermeulen et al. Annotating traversable gaps in walkable environments. In Int. Conf. on Robotics and Automation, 2018.

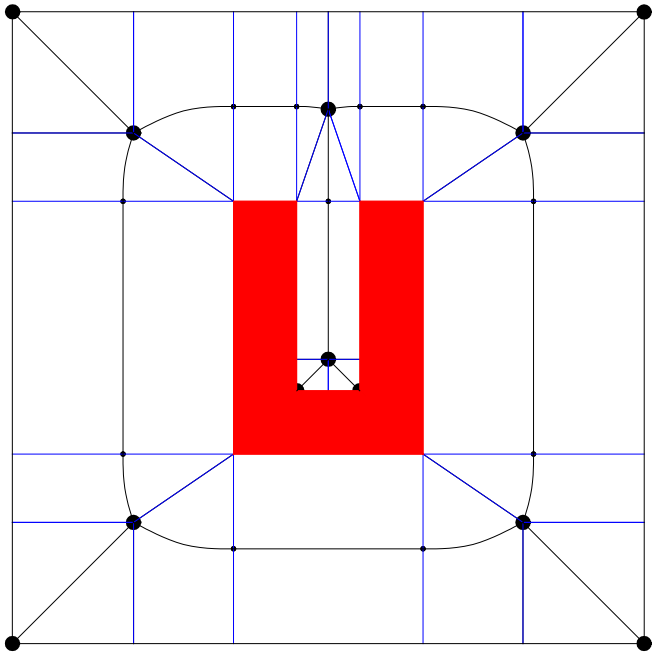
From 3D geometry to a navigation mesh

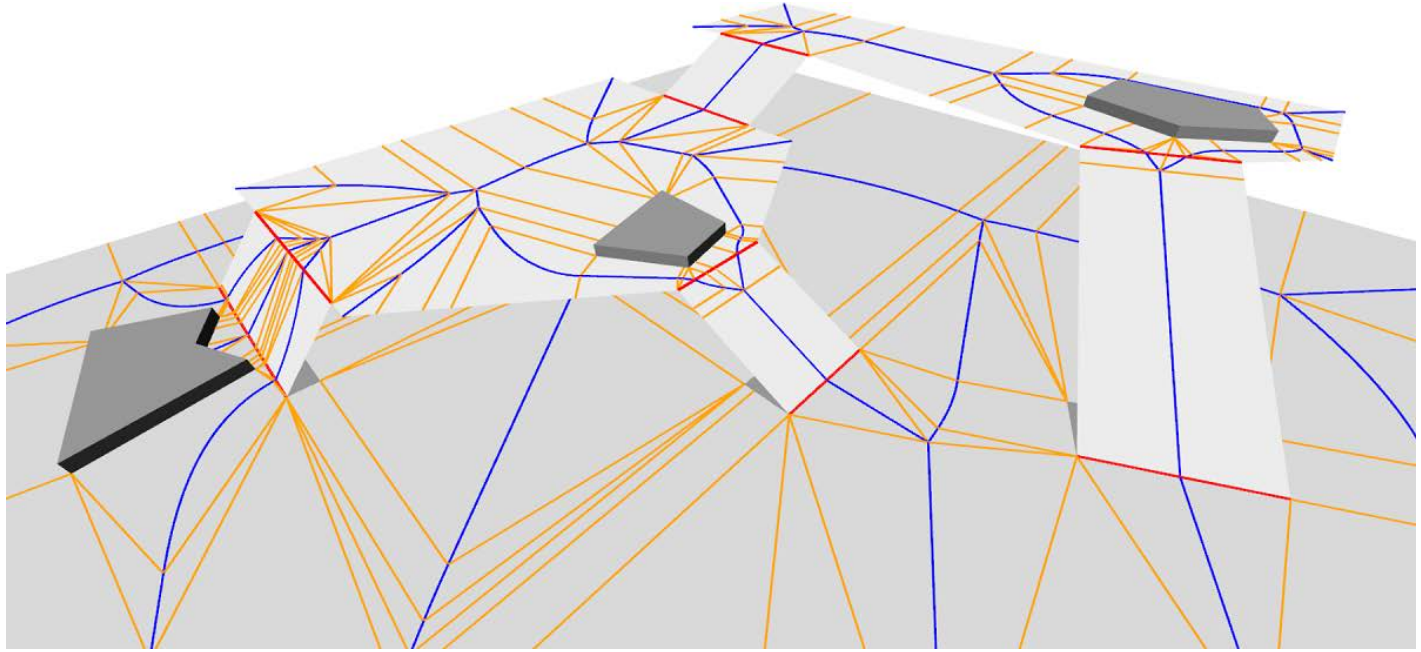
that has nice properties and can be queried fast

From 3D geometry to navigation mesh

What is the best representation for the walkable space of a *multi-layered 3D* environment?

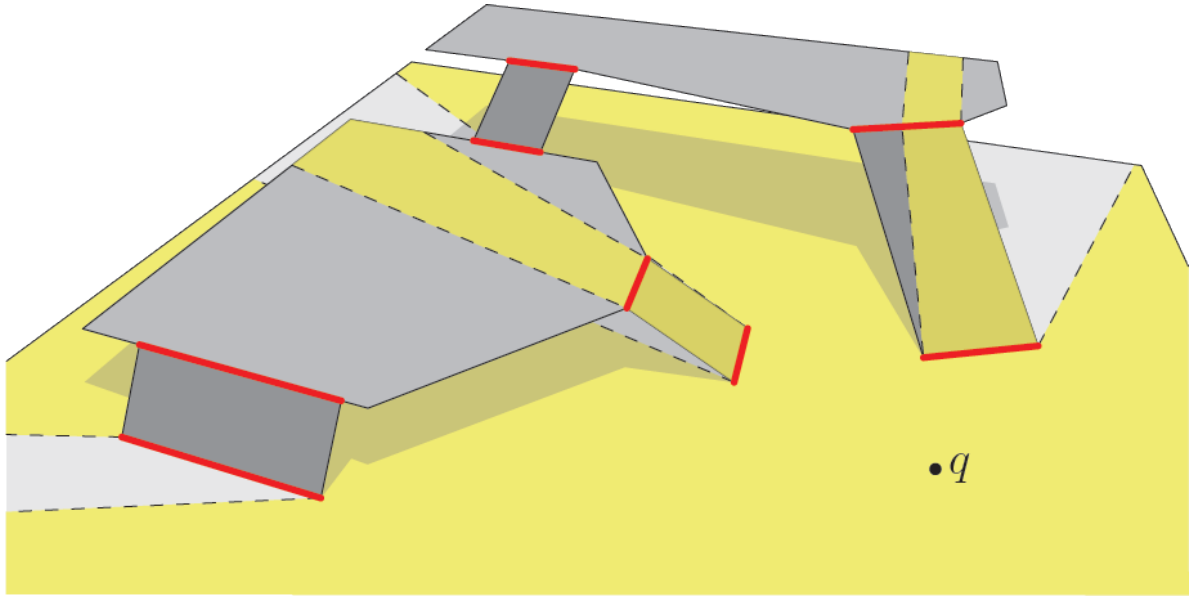
- Compute a 2D navigation mesh per layer
- Stitching the navigation meshes

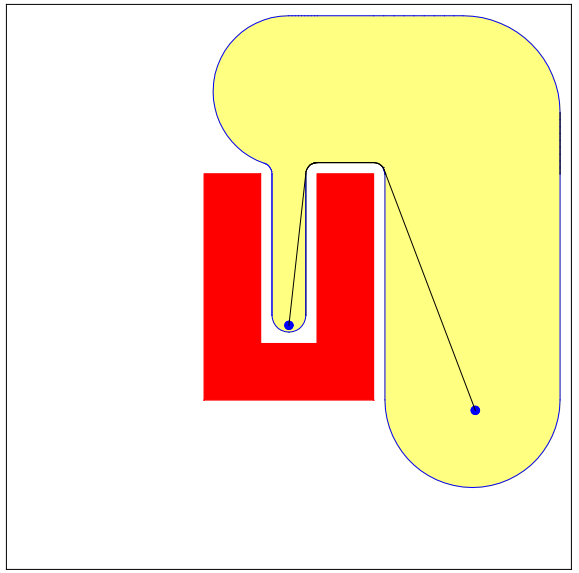


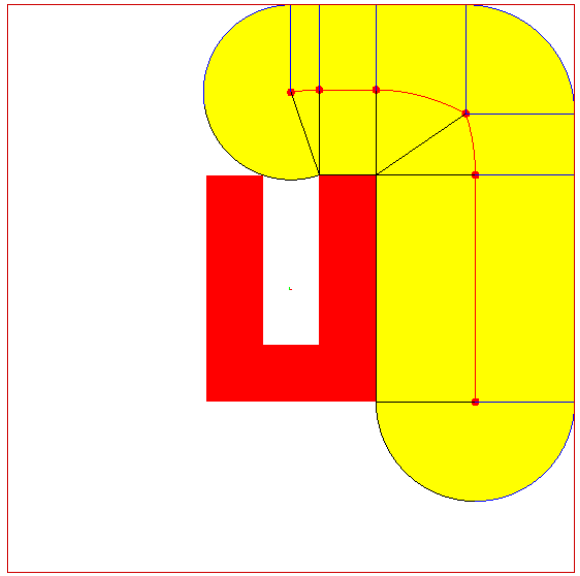


From 3D geometry to navigation mesh

- Favorable properties

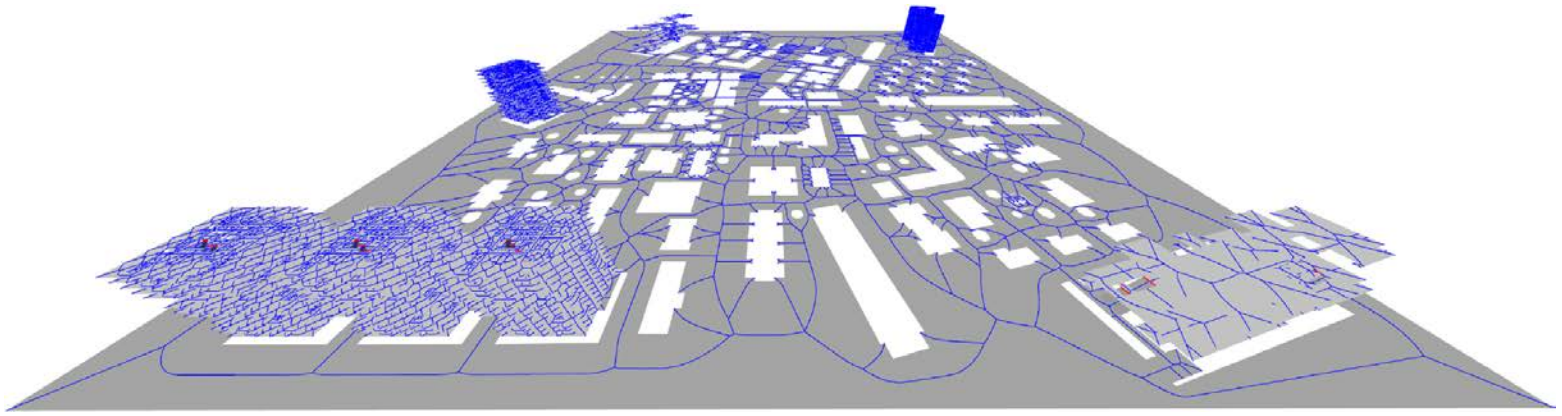


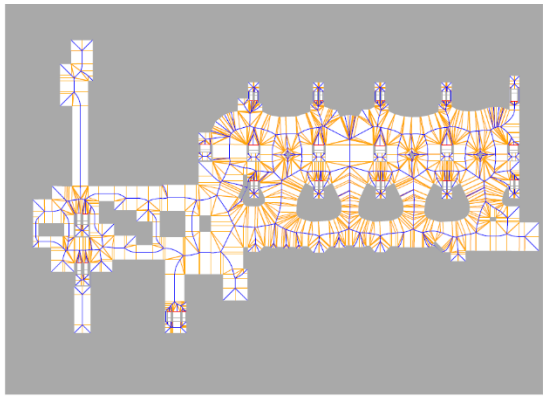


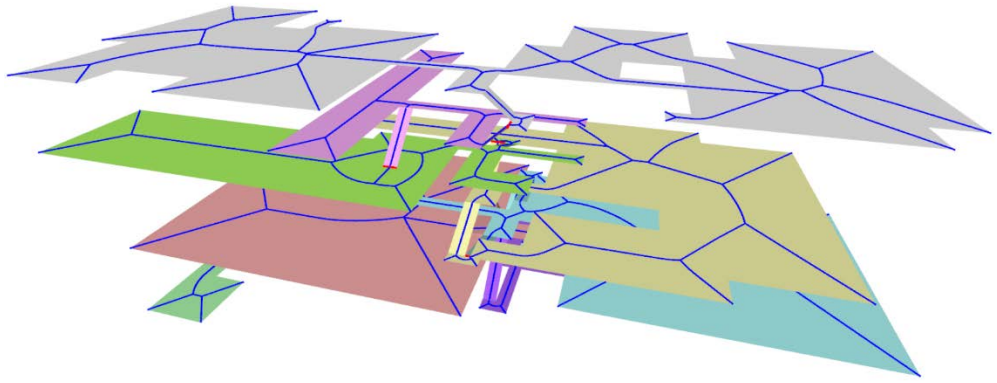


From 3D geometry to navigation mesh

- Large environments are processed within 1 second



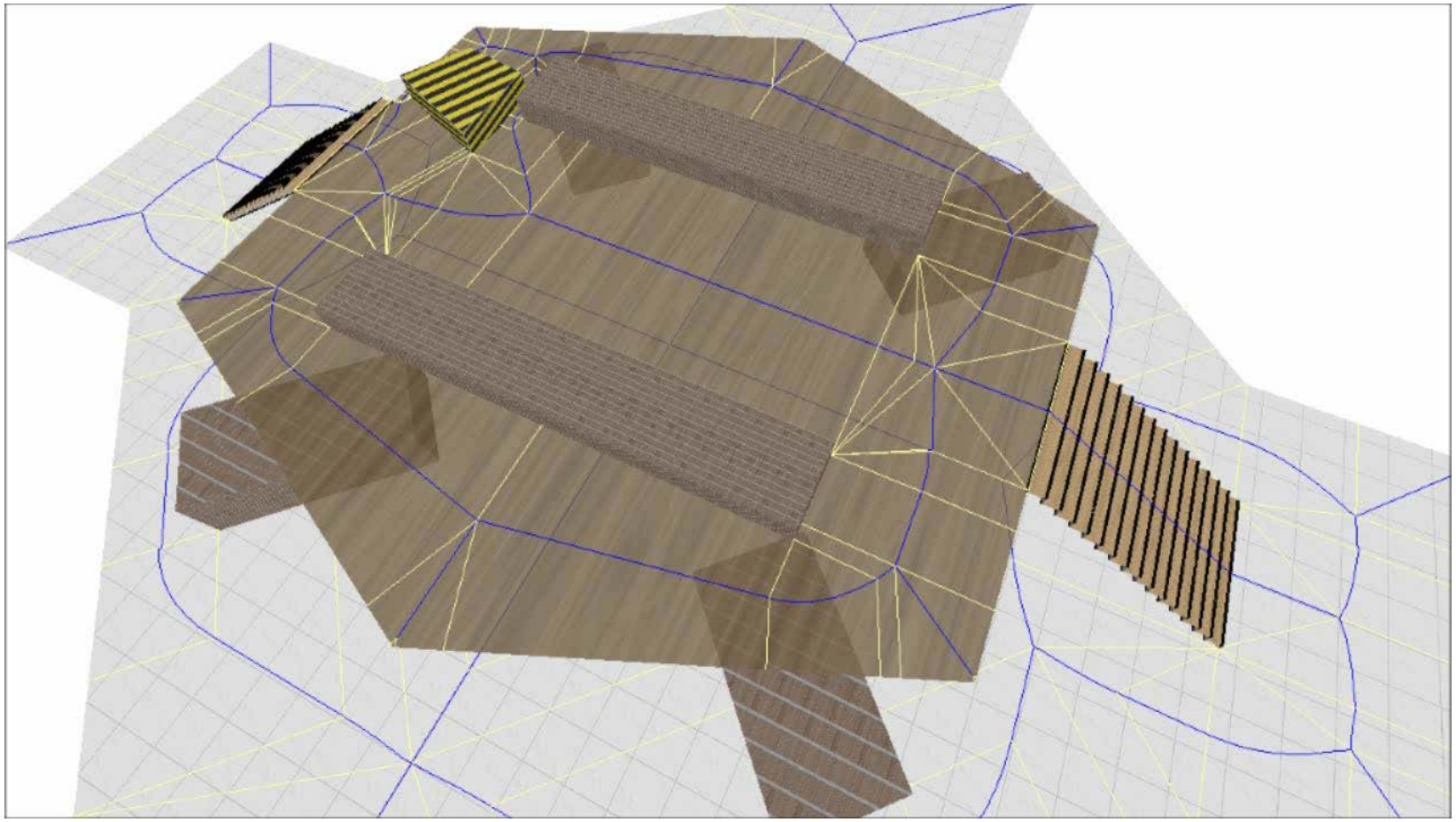




van Toll et al. The Medial Axis of a Multi-Layered Environment and its Application as a Navigation Mesh. Trans. on Spatial Alg. & Syst.. 4(1), 2018.

From 3D geometry to navigation mesh

- Handles dynamic updates



From navigation mesh to simulation of 1 pedestrian

Crowd simulation framework

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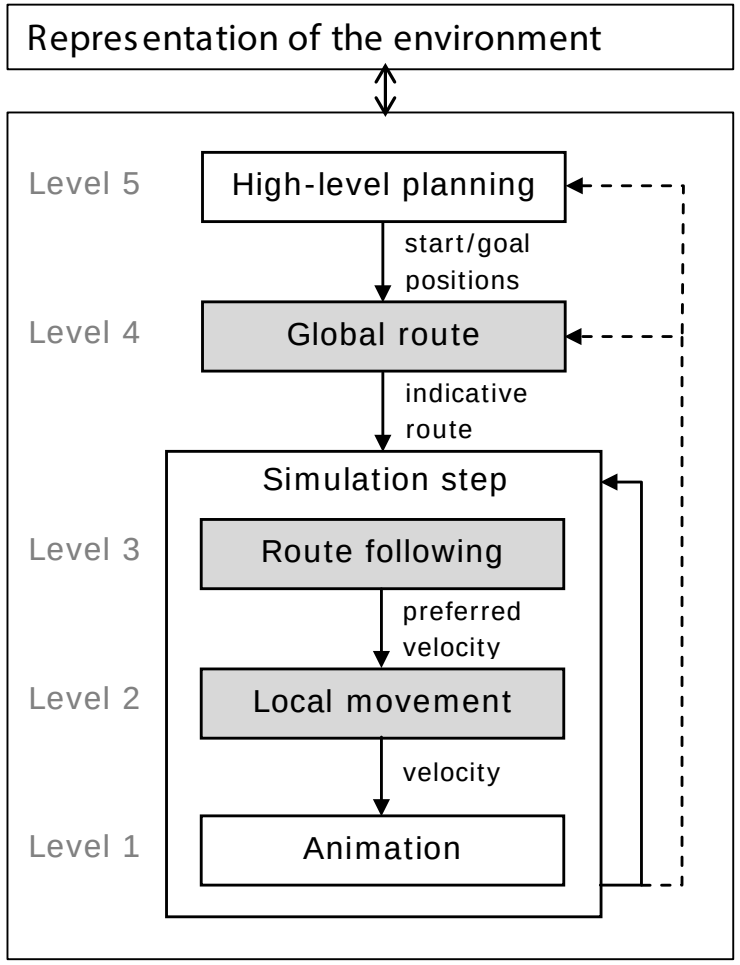

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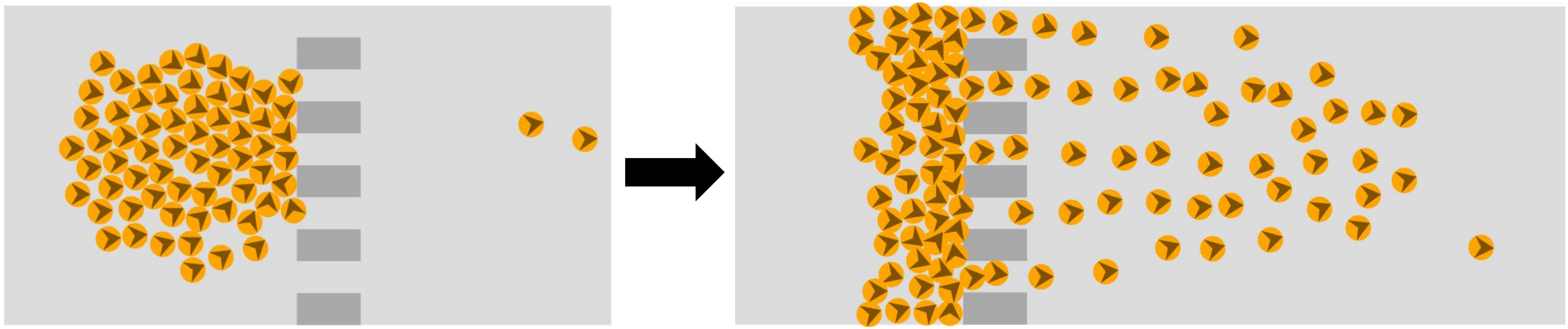
Action planning

- Splits up a task into geometric queries
  - Example: dynamic updates of the crowd



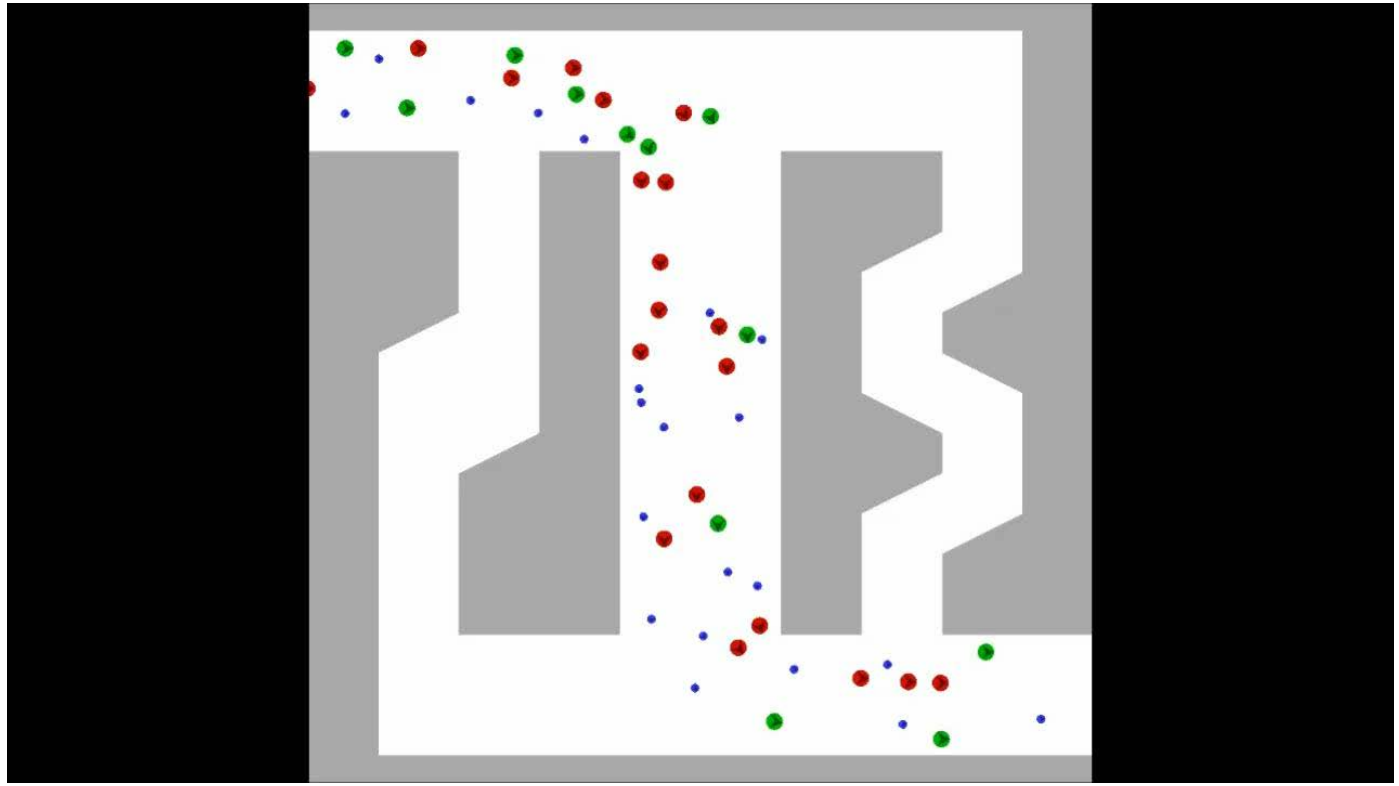
Standard behavior: pedestrians take the same terminal

Improved behavior: pedestrians distribute amongst all terminals

M. Koenis, 2016: Impact of Pedestrians Bringing Along Their Bicycles on Evacuation Times of Subway Stations

Action planning

- Splits up a task into geometric queries
  - Example: dynamic updates of the crowd



Small agents
Commuters (aware of change)
Incidental visitor (not aware)

Dynamic obstacle

Van Toll et al, 2015: Dynamically Pruned A* for Replanning in Navigation Meshes

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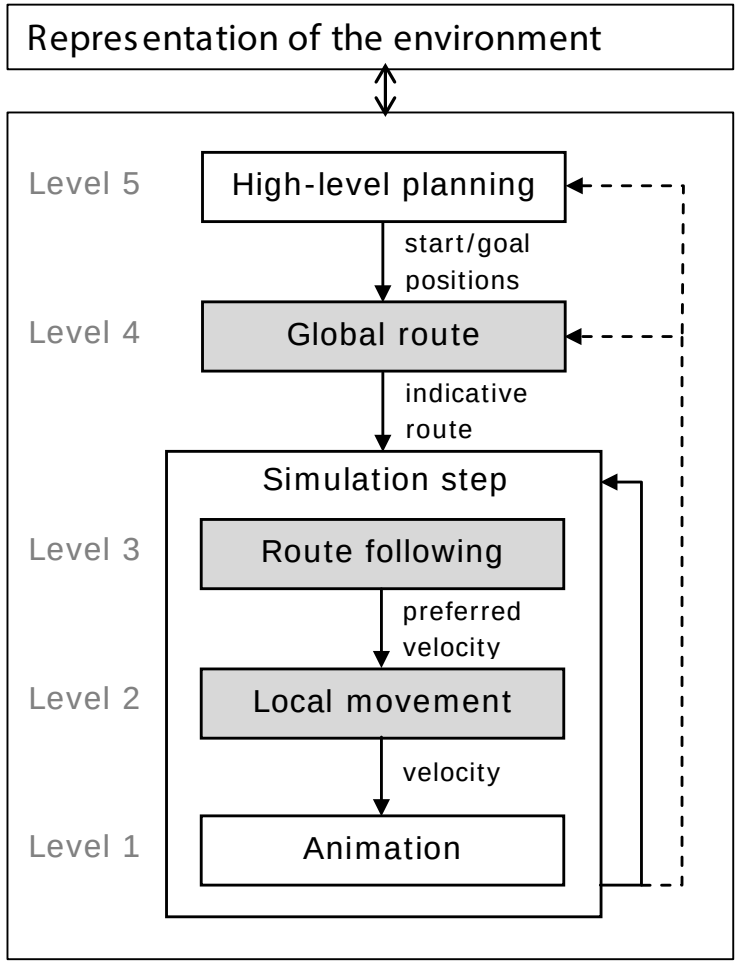

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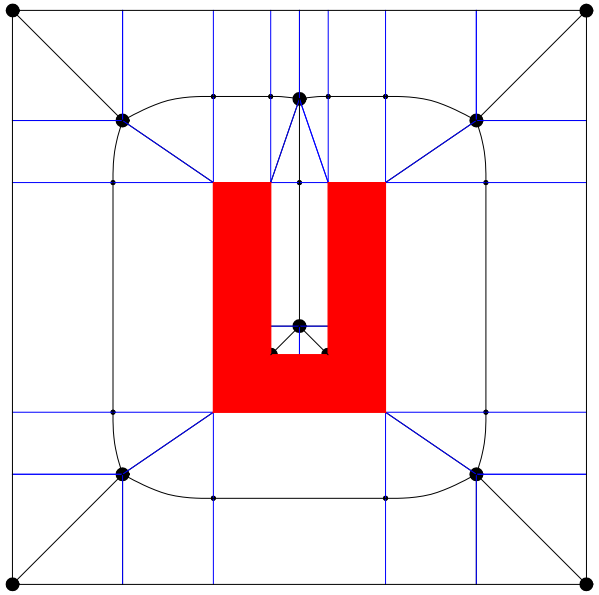
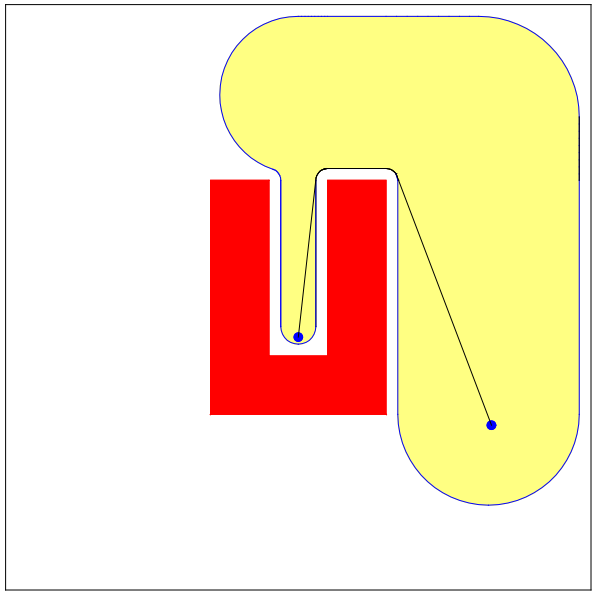
Indicative Routes

- A path planning algorithm should NOT compute a path
  - A one-dimensional path limits the agent's freedom
  - Humans don't do that either
- It should produce
  - An Indicative/Preferred Route
  - A corridor around this route

Computing Indicative Routes

- Example: shortest path with clearance to obstacles





Jaklin et al, 2014: Computing High-Quality Paths in Weighted Regions

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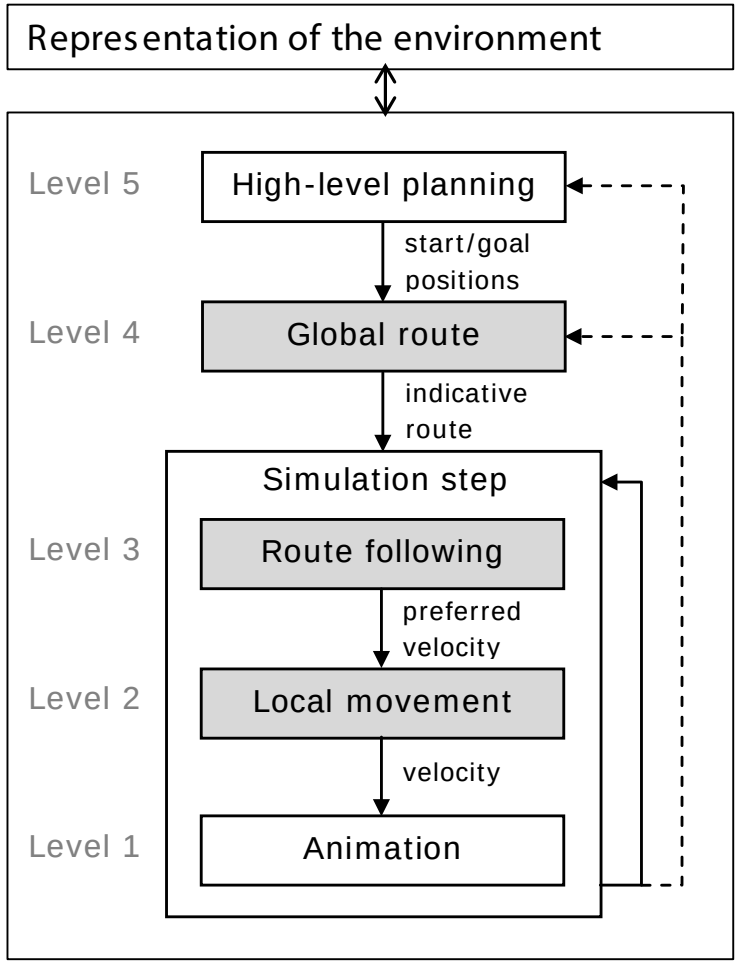

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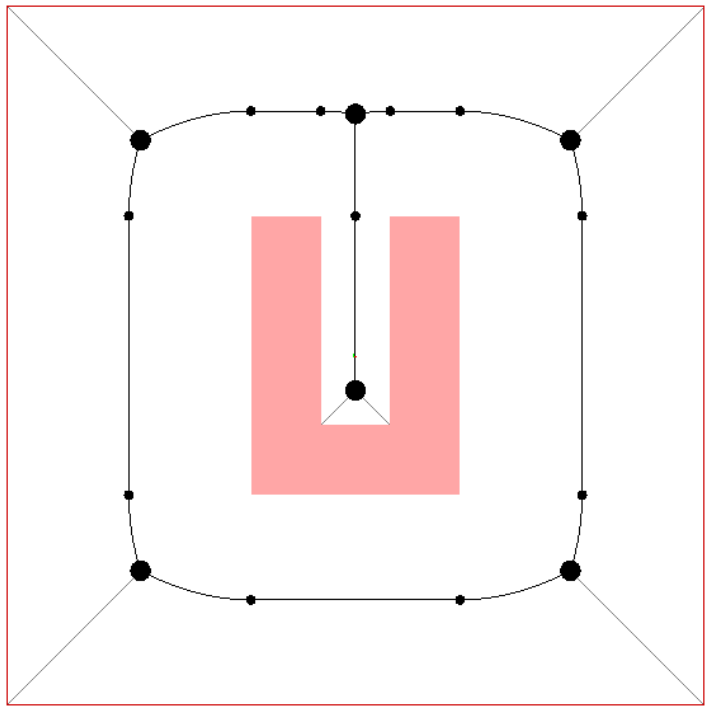
Following routes

- Basic algorithm
  - An attraction point on the indicative route guides the pedestrian to its goal
  - Obstacles repulse pedestrians when they are too close



From simulation of 1 pedestrian to a crowd

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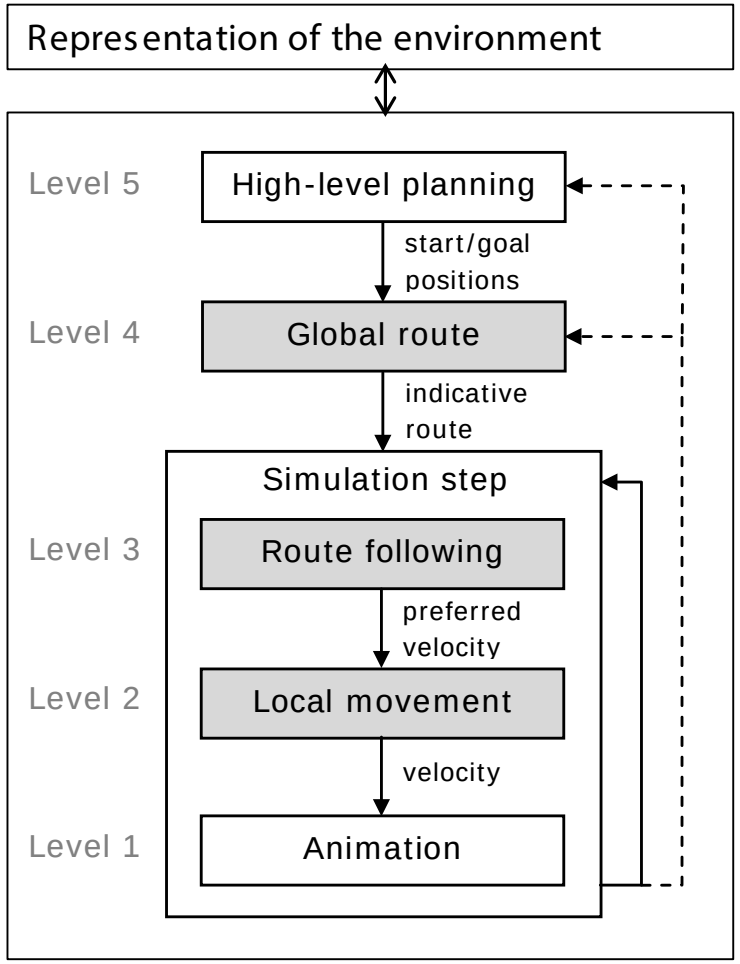

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Towards Believable Crowds: A Generic Multi-Level Framework for Agent Navigation.

What is realistic collision-avoidance behavior?

Smack the pony s01x02

What is realistic collision-avoidance behavior?

Crowd prank in Japan

Adapting the routes: Collision avoidance

- Our model is derived from experiments in the MOCAP lab

PhD students: Wouter van Toll and Norman Jaklin

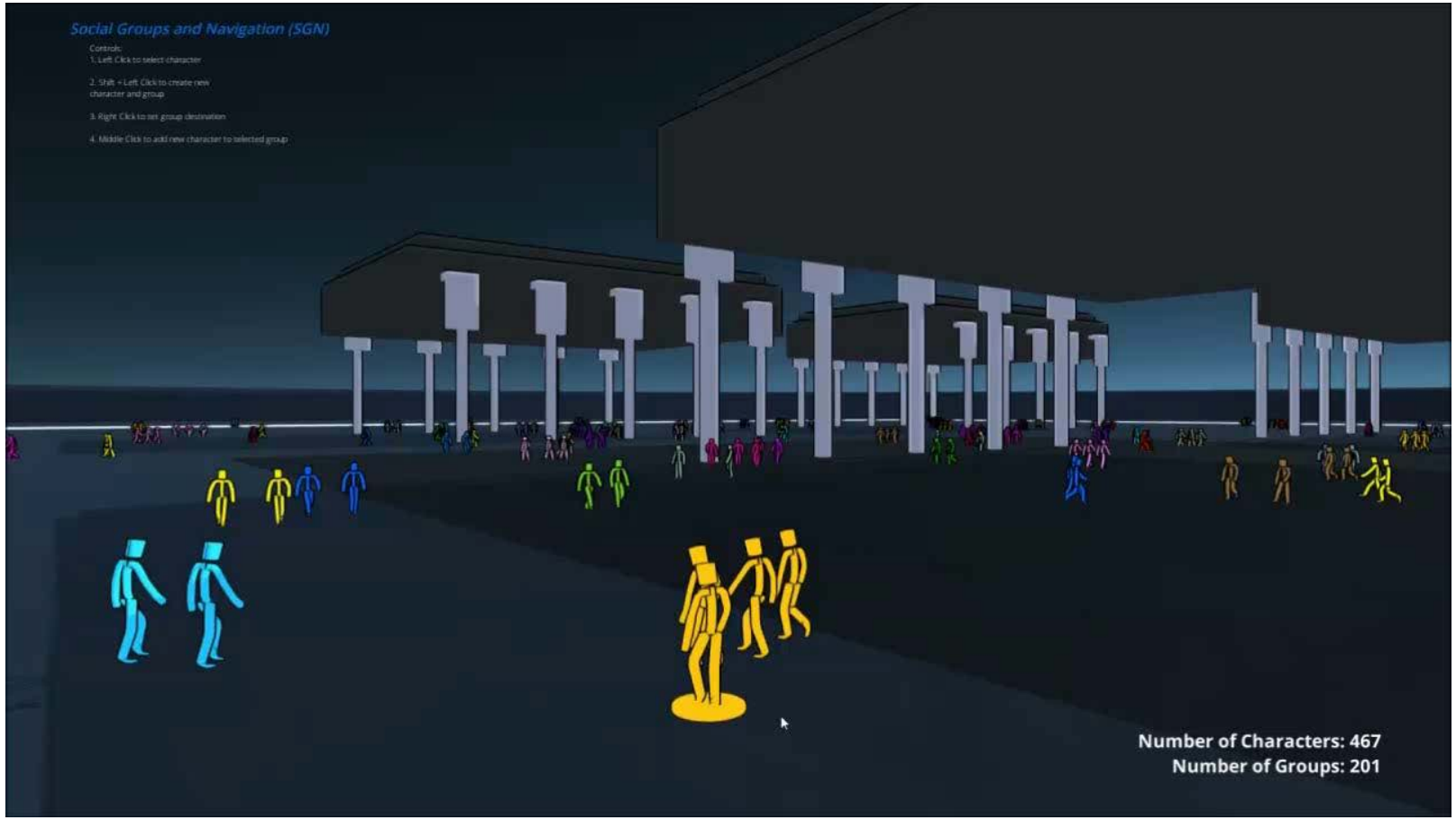
Adapting the routes: Collision avoidance

- Our model slightly adjusts the people's movements

Karamouzas et al, 2009: A Predictive Collision Avoidance Model for Pedestrian Simulation

Adapting the routes: Social groups

- The group members stay close and visible to each other



Kremyzas et al, 2016: Towards Social Behavior in Virtual Agent Navigation

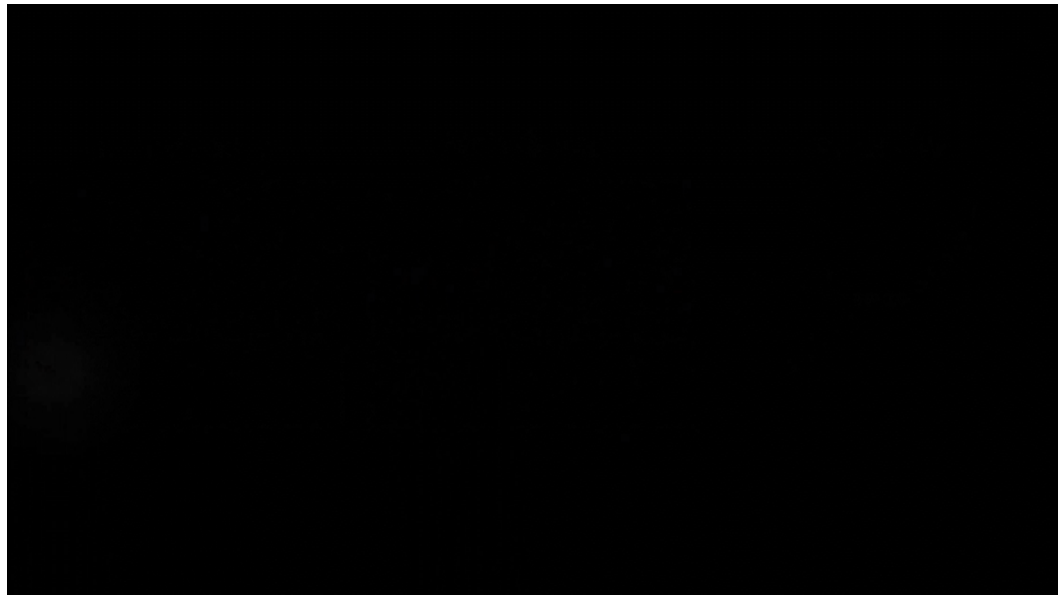
Adapting the routes: Moving through a dense crowd

- People can make room for a passing individual

Stüvel et al, 2017: Torso crowds

Adapting the routes: Unification of individual and collective movements

- Our stream-based model allows local coordination, based on a agent's incentive
  - Deviation from the local flow
  - Local density
  - Internal motivation
  - Spent time to reach goal



Van Goethem et al, 2015: On Streams and Incentives: A Synthesis of Individual and Collective Crowd Motion

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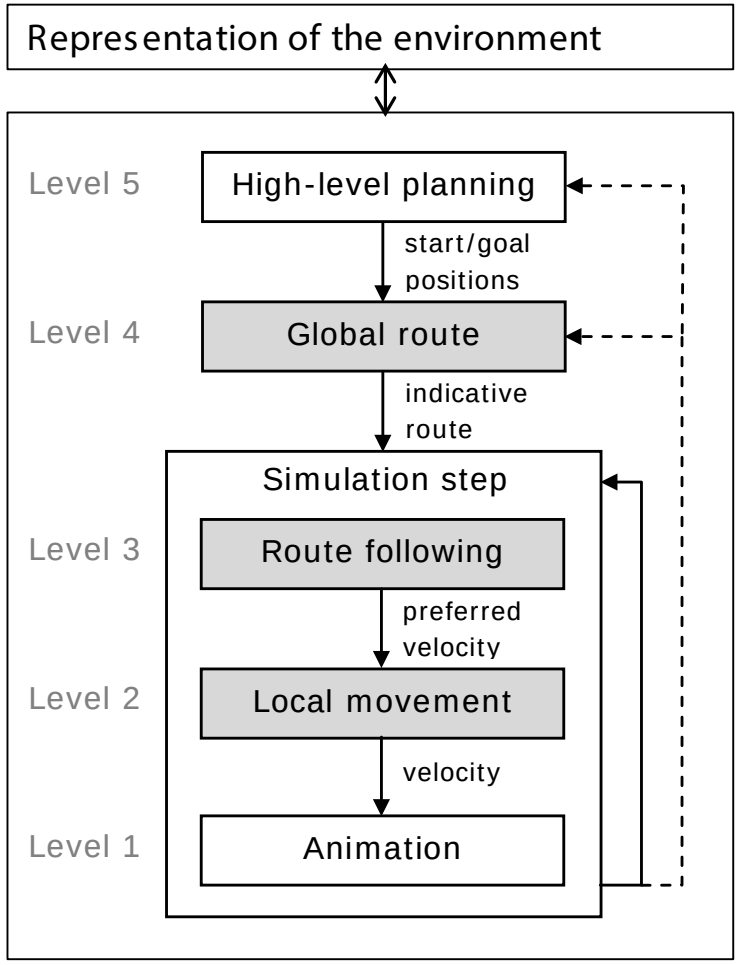
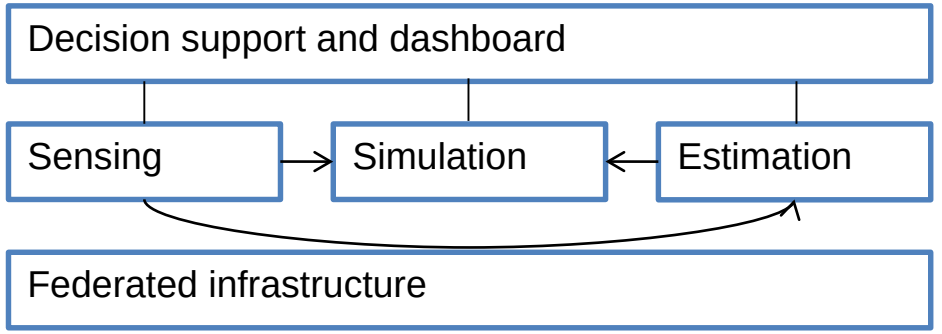


Van Toll, Jaklin, and Geraerts, 2015. Towards Believable Crowds: A Generic Multi-Level Framework for Agent Navigation.

Current developments

- Real-time crowd prediction, analysis and decision support
  - A sensing system computes the pedestrians' positions
  - This calibrates the simulation in real -time with the real world
  - Makes predictions of the coming minutes
  - May run 24/7
  - Prevents unsafe situations and make the city / station safer
  - Special attention is paid to preserving privacy and complying with ethical requirements set by society



Software

Software package

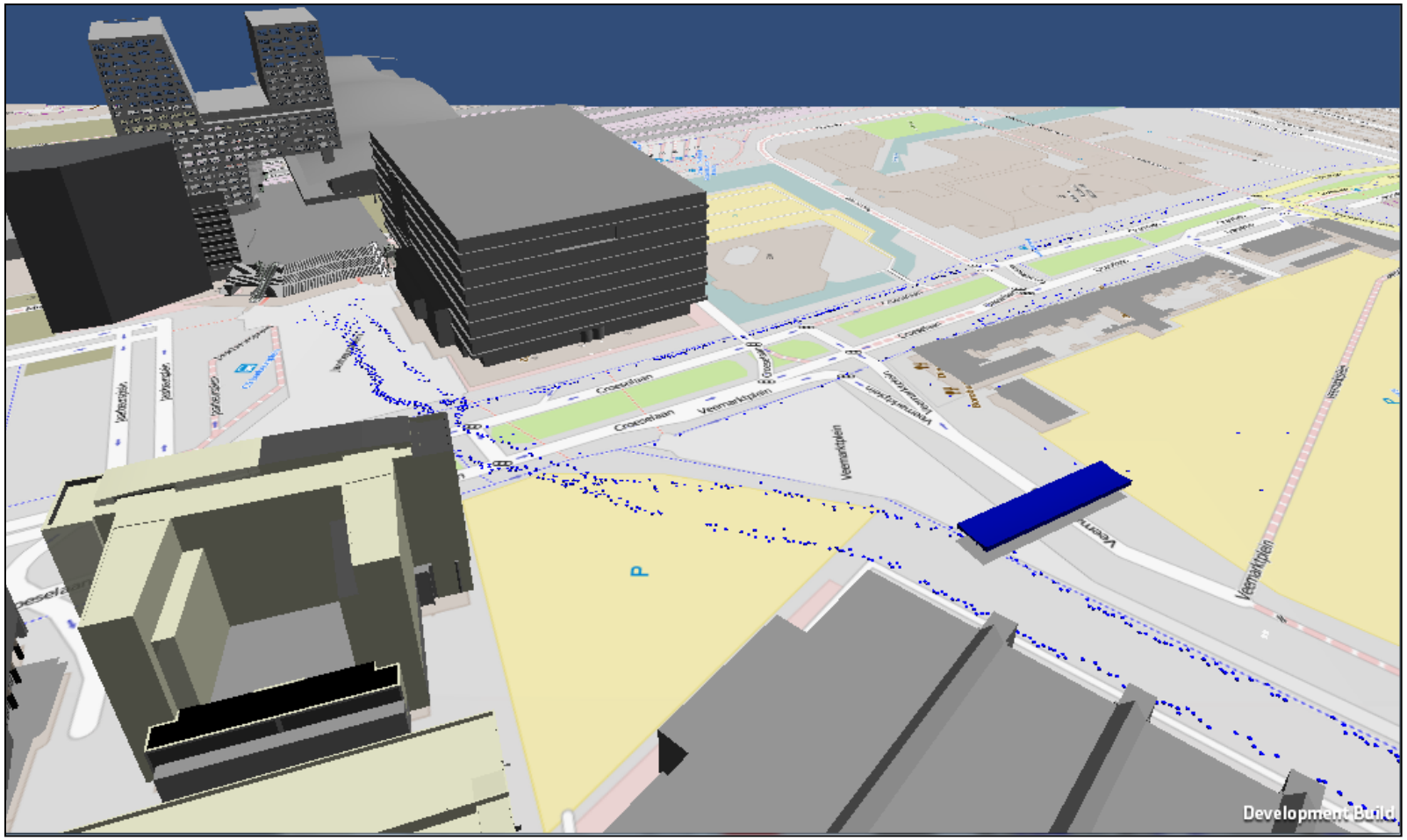
- Core engine in C++
- Runs on 64bit Windows
  - Linux, MacOS, iOS
- Also available as a plugin for Unity3D
  - https://ucrowds.com/documentation/unity3d/
- To obtain a license, send a request
  - Our startup
  - info@ucrowds.com

UCrowds

Applications

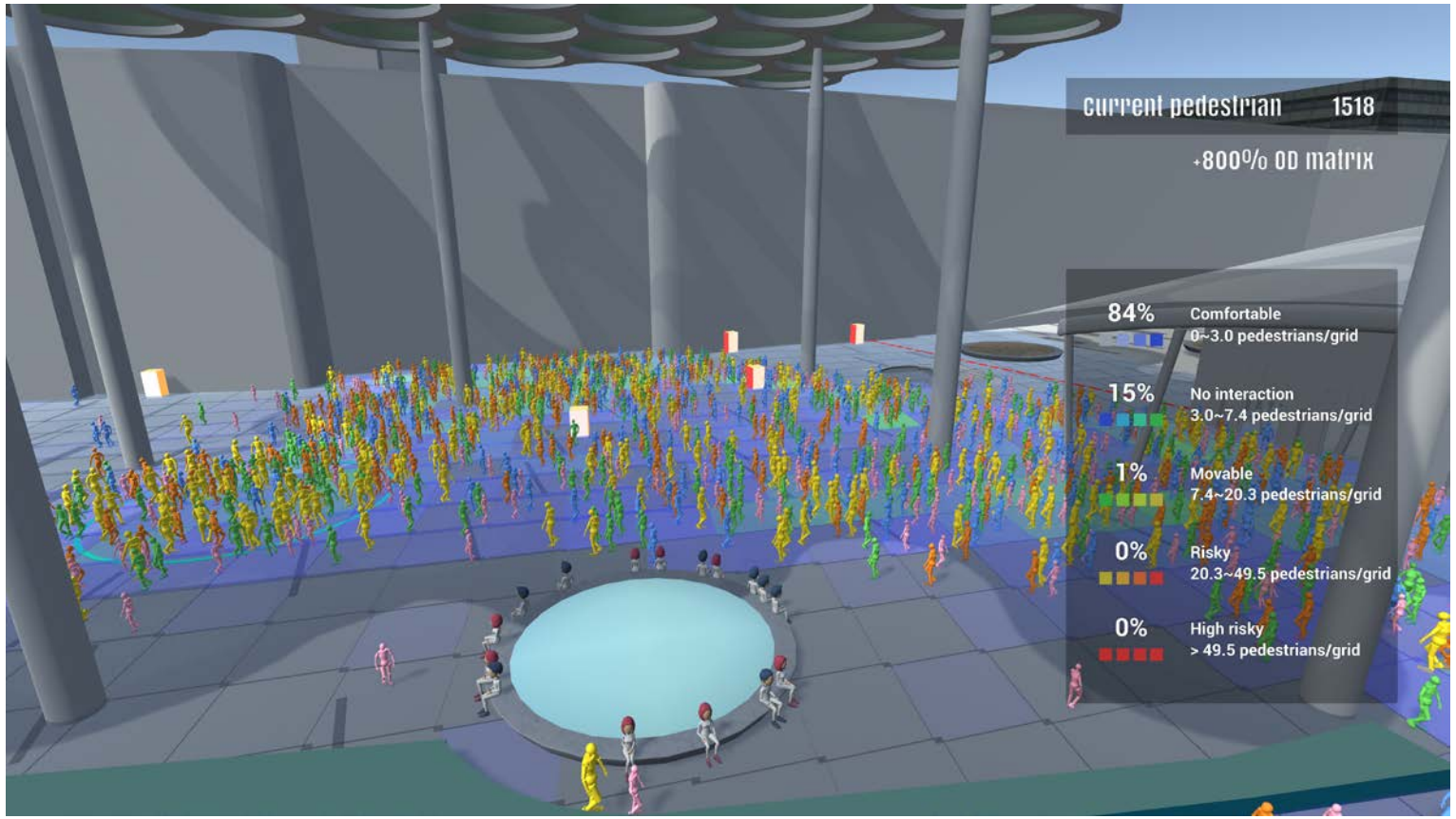
Optimizing crowd flows

Tour de France



Optimizing of outdoor area layout

Utrecht Stationsplein

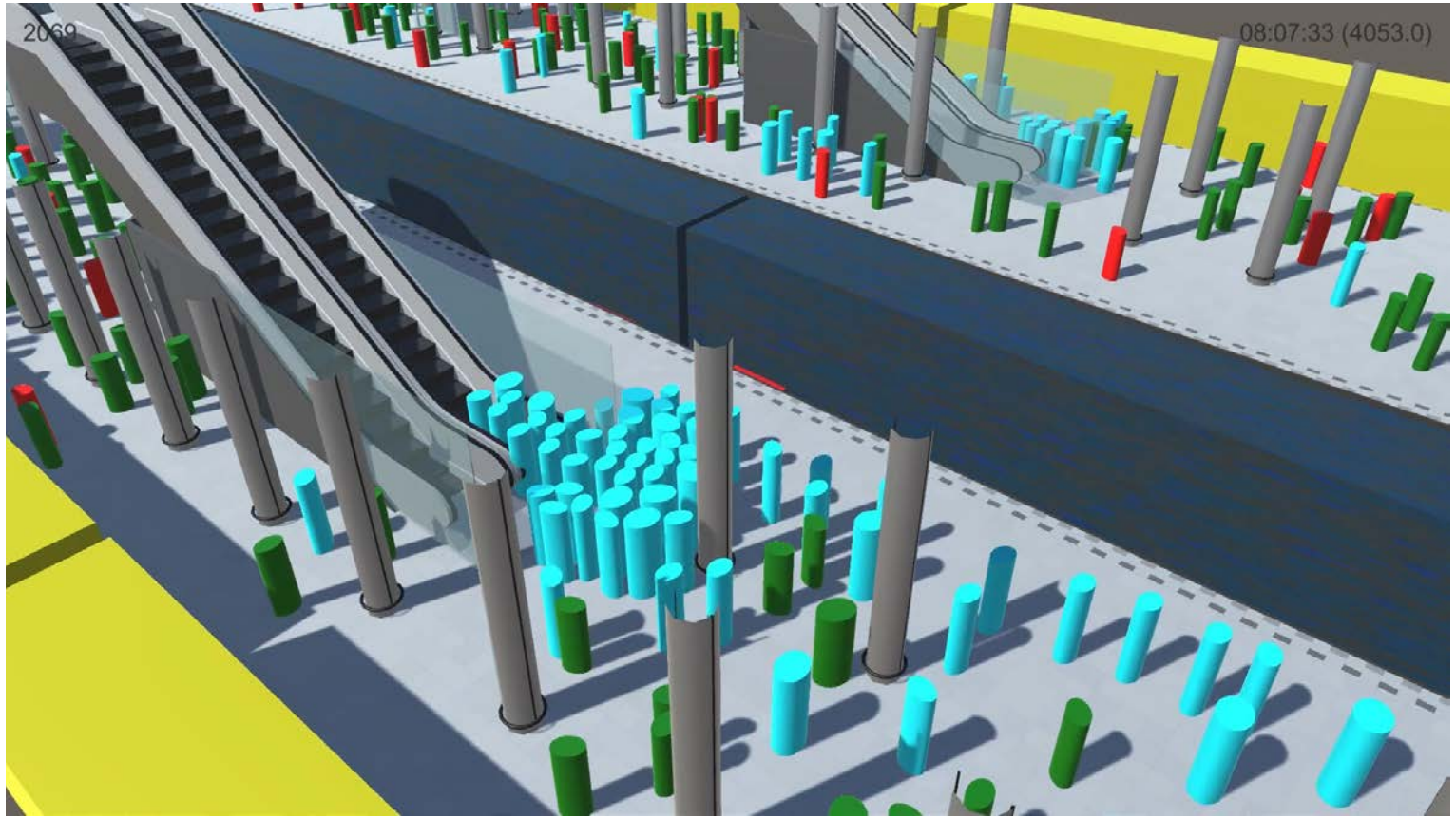


Evacuation studies (with bicycles)

Metro stations before operation

Conducting what-if scenarios

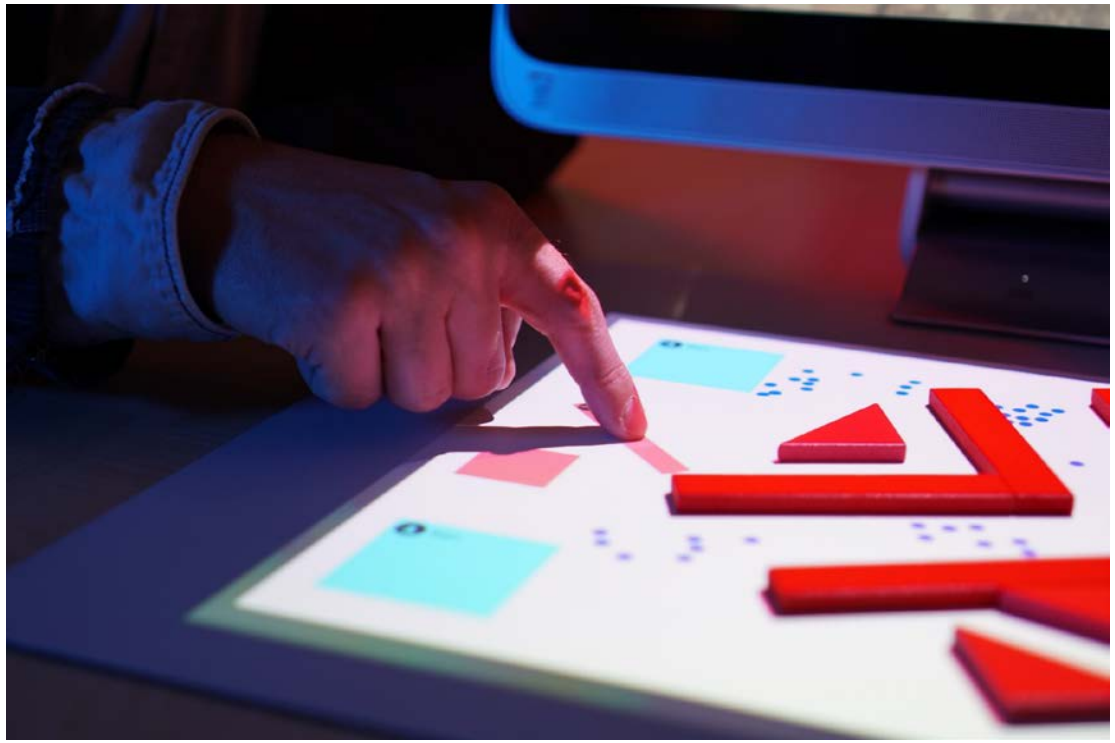
Rail at transport hub



Tangible interaction

Education and training

Public engagement



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