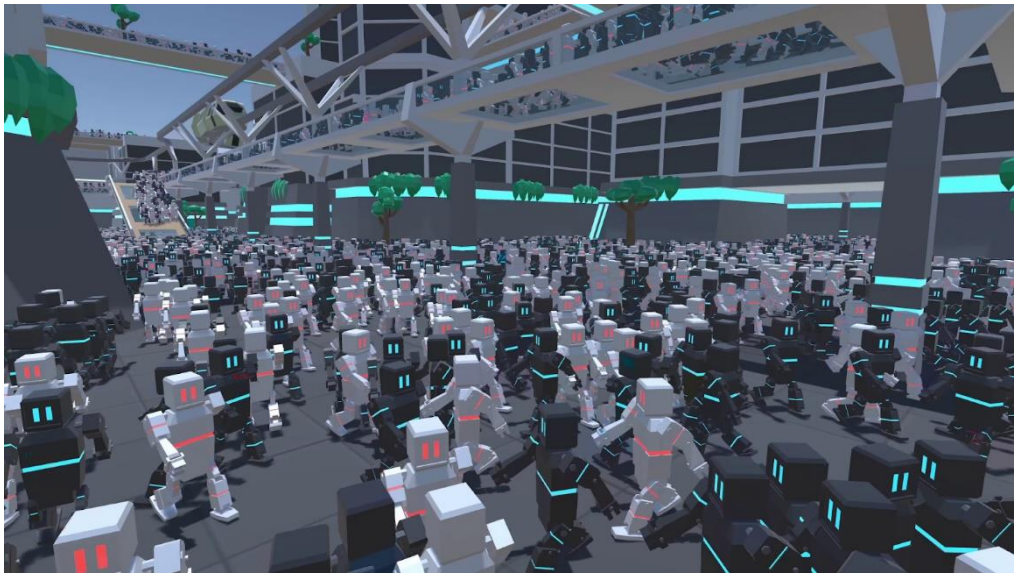
Optimization & vectorization

UU Crowd Simulation Software

Roland Geraerts

October 14, 2019



Unity3D plugin

UU Crowd Simulation R&D

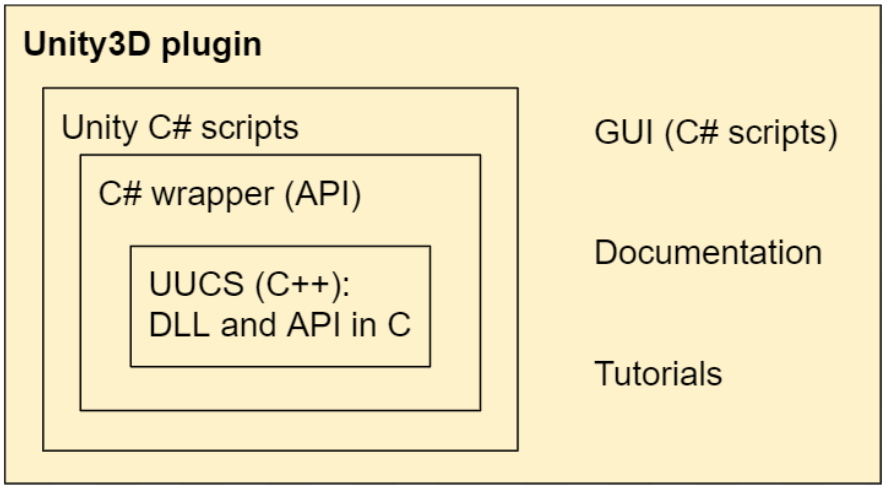
Unity3D Plugin

Utrecht University

GENTLE Melon studios

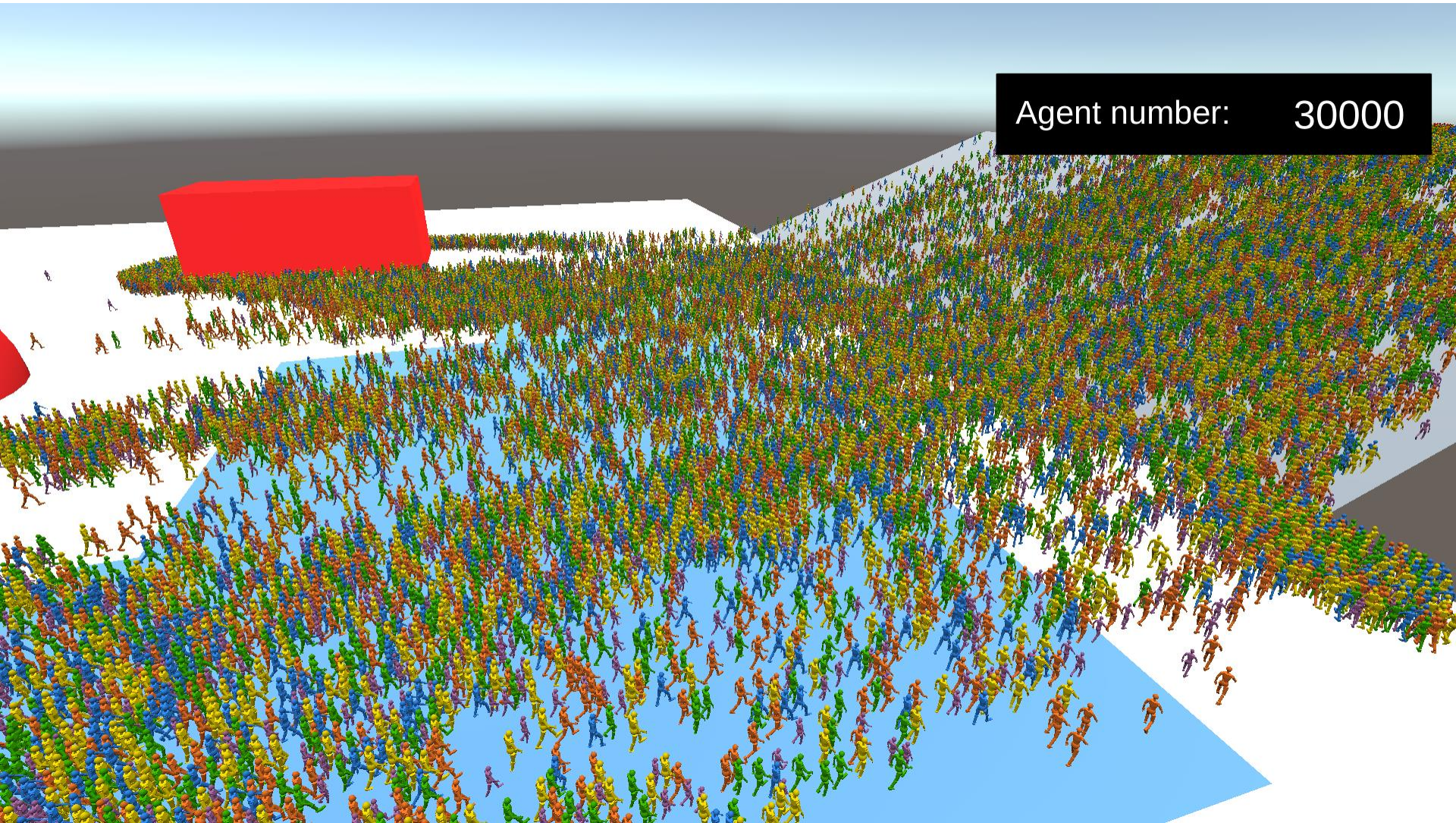
However…

- Global framework
  - Agents are simulated in parallel using OpenMP



- Real-time performance
  - UUCS: simulates 15K agents
  - Unity: animates and visualizes 1.5K agents

30K in real-time on a fast laptop



What changed?

- UUCS
  - Made some remaining code run in parallel
- Unity
  - From objected oriented to data driven implementation
    - Entity component system & Job system
  - From main thread to separate threads
  - From CPU animations to GPU shader-based animations

However…

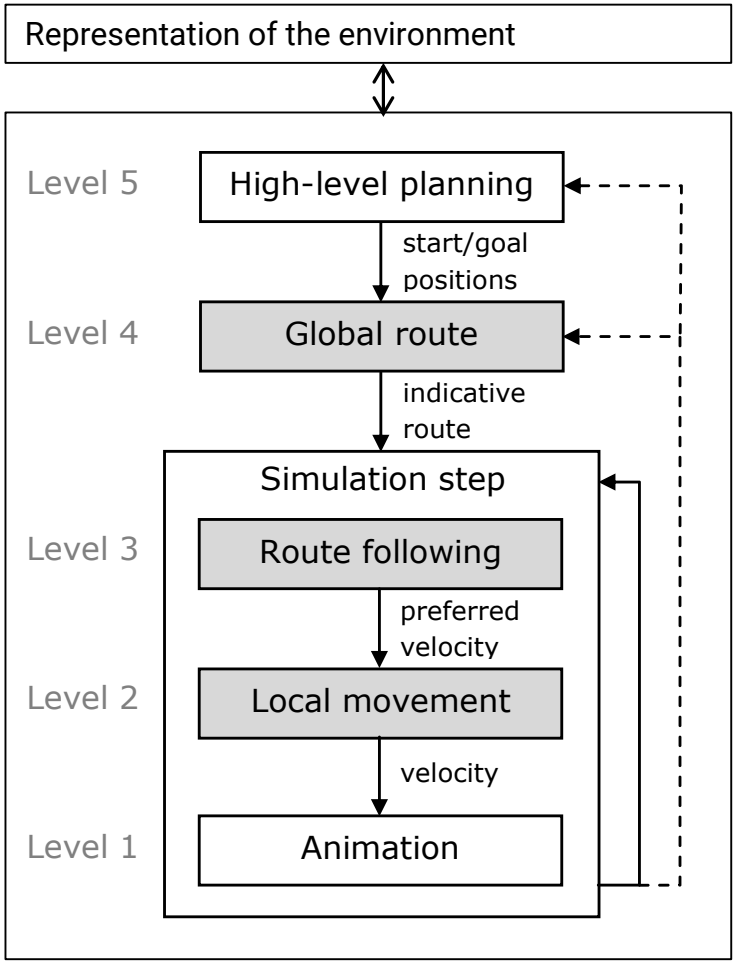
- Current optimizations in UUCS
  - Theoretical running times: O(…)
  - Parallel code using OpenMP
- So much is still possible…
  - …but we first need to understand the framework

How

can you simulate a human crowd *interactively*?

Crowd simulation framework

- Representation environment
- Level 5
  - Plans actions
- Level 4
  - Creates indicative routes
- Level 3
  - Traverses the routes
  - Yields speed/direction pairs
- Level 2
  - Adapts routes
  - E.g. to avoid collisions
- Level 1
  - Moves the agents



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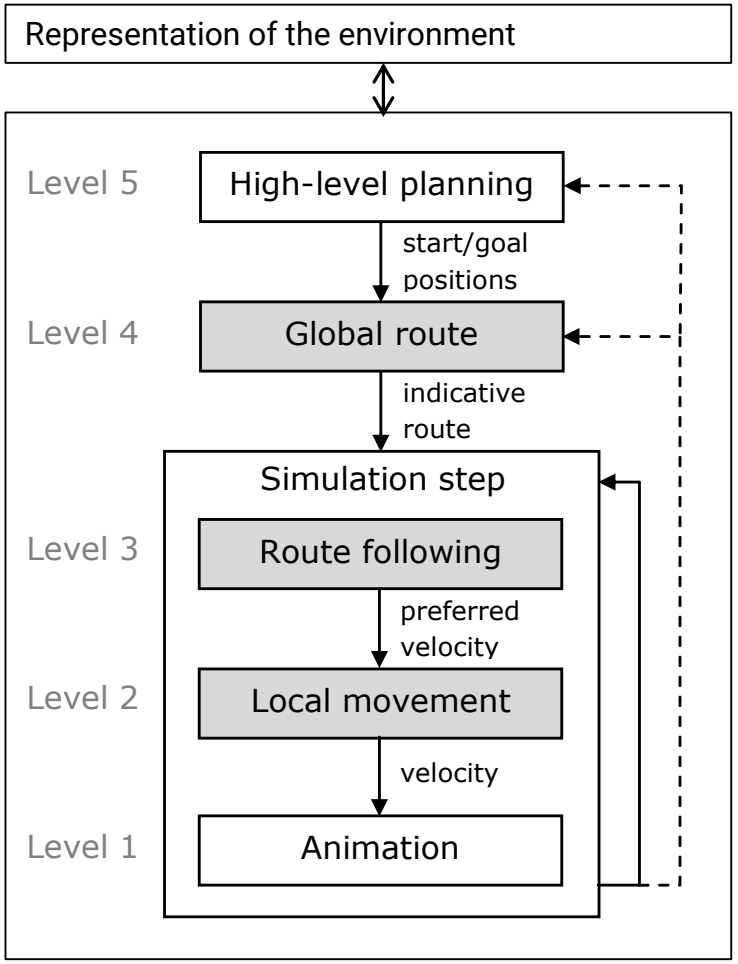
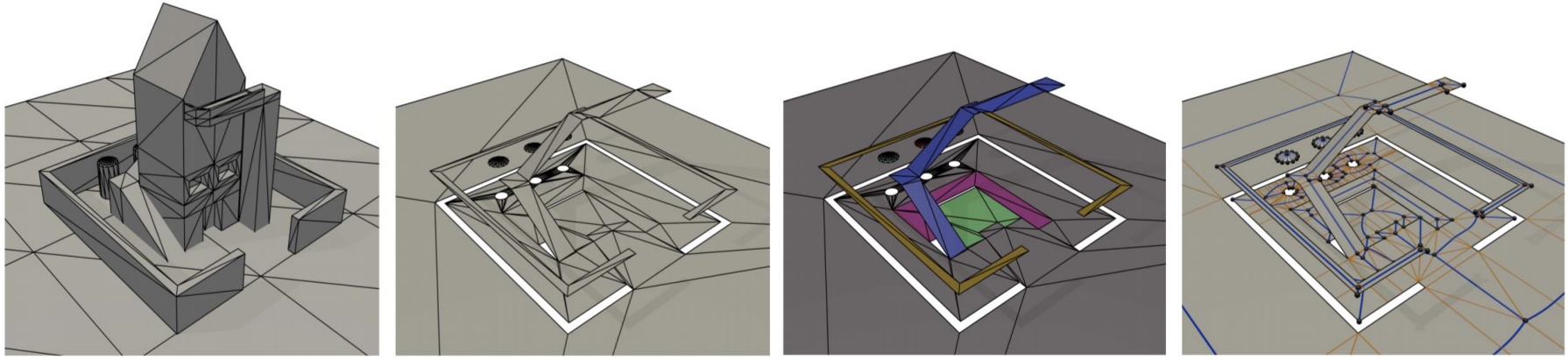
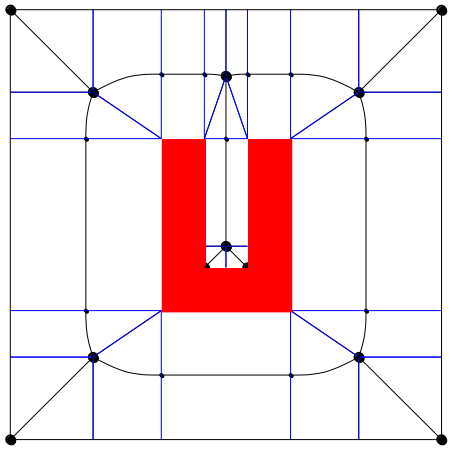


Representation of the environment

- Computation of walkable areas and navigation mesh



Van Toll et al, 2018: The Medial Axis of a Multi-Layered Environment and its Application as a Navigation Mesh



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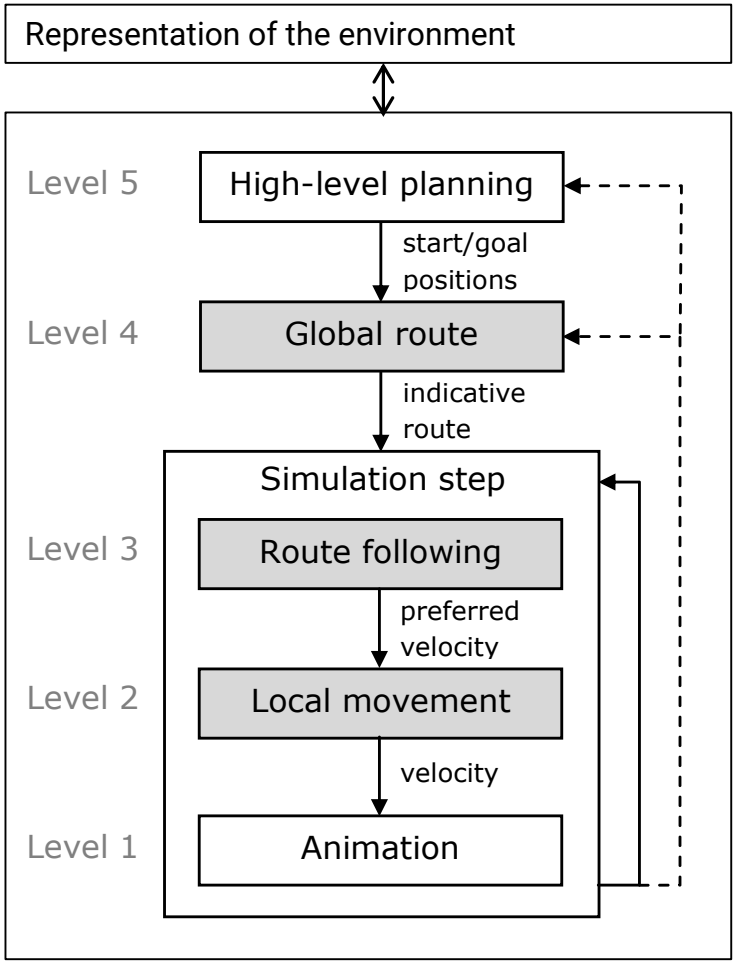
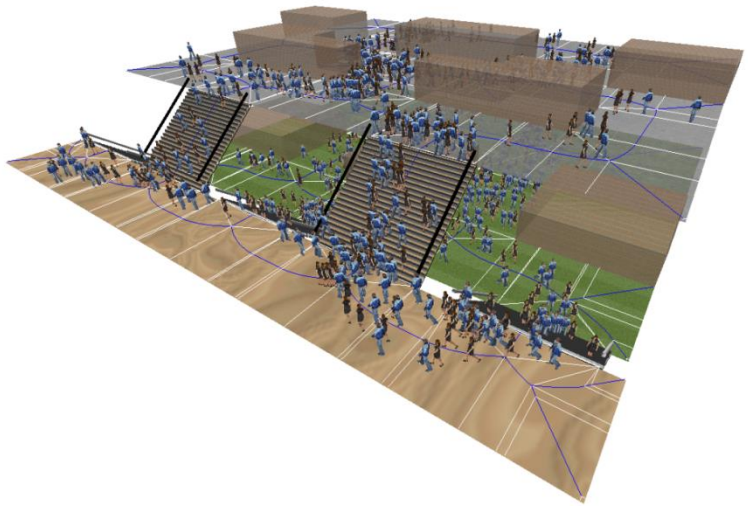


Level 4: Indicative routes

- We use the Explicit Corridor Map (ECM)
  - Compact navigation mesh
  - Supports any agent radius
  - Multi-layered environments
  - Dynamic updates



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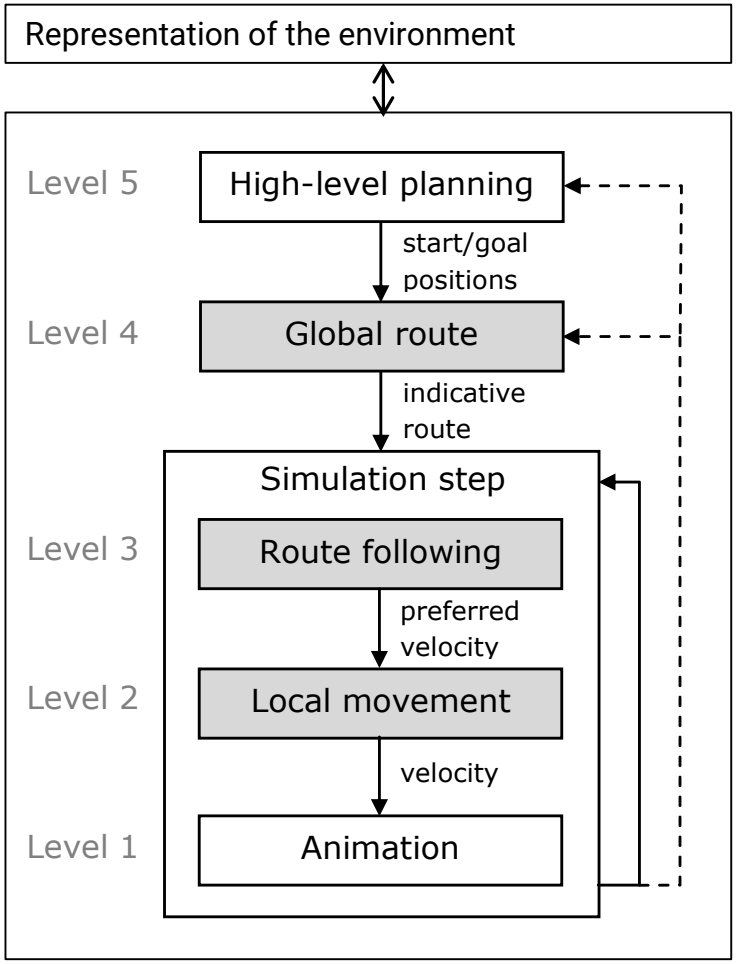
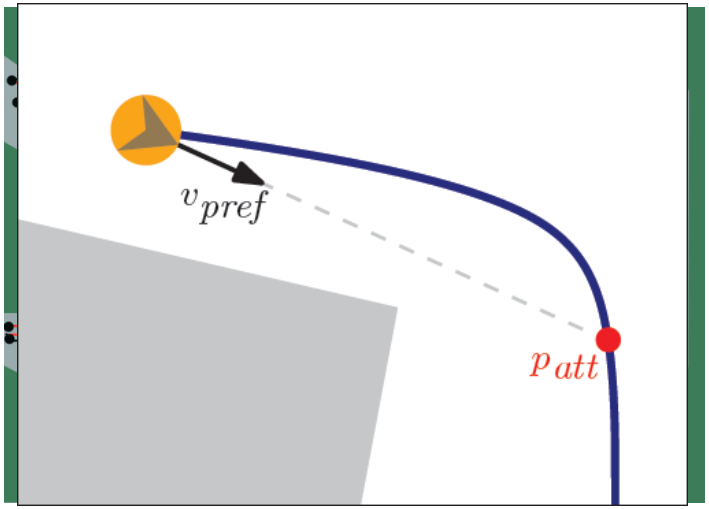


Level 3: Path following

- Smoothly follow a desired path
  - Input: indicative route, non-smooth indication of the path
  - In each simulation step, compute an attraction point
  - Leads to a preferred velocity for the next level
- Indicative Route Method (IRM, 2009)
- MIRAN: improvement by Jaklin et al. (2013)
  - Supports weighted regions
  - Better smoothness/ shortcut control



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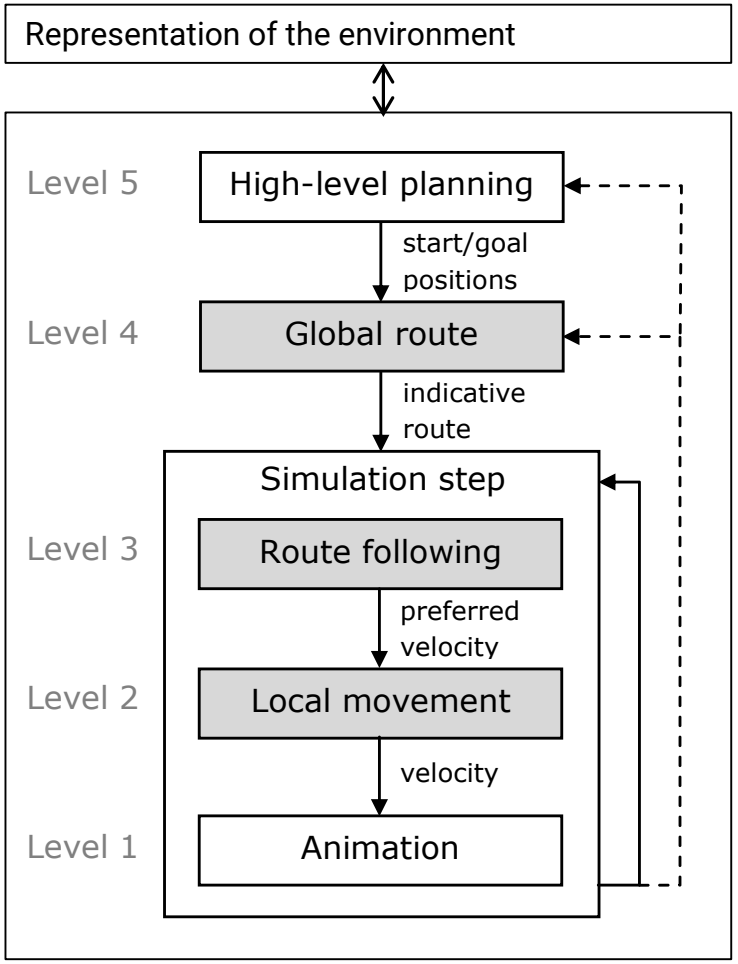
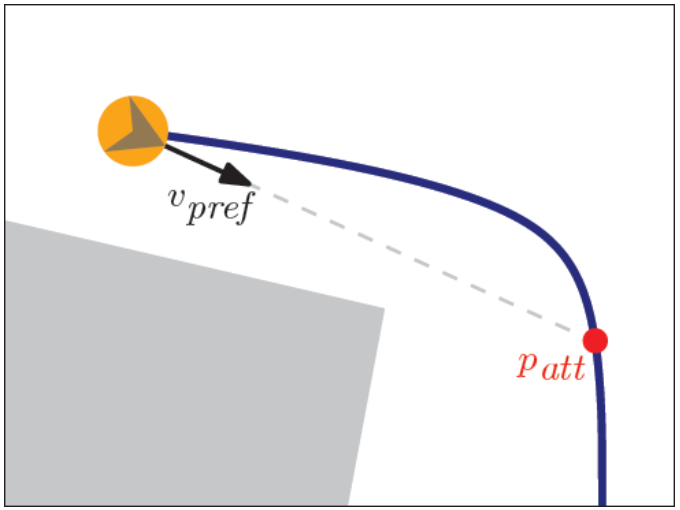
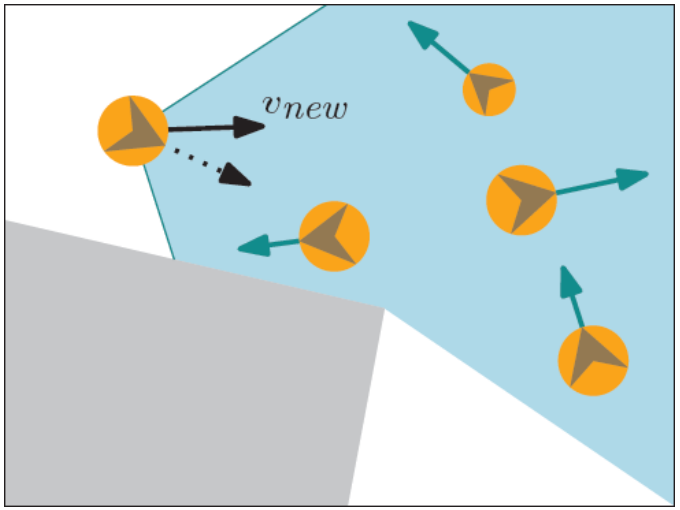


Level 2: Local movement

- Roughly move in the preferred direction, while...
  - ...responding to collisions with other characters
  - ...avoiding future collisions
  - ...adapting to the surrounding streams of people
  - ...maintaining social group behavior
  - etc.





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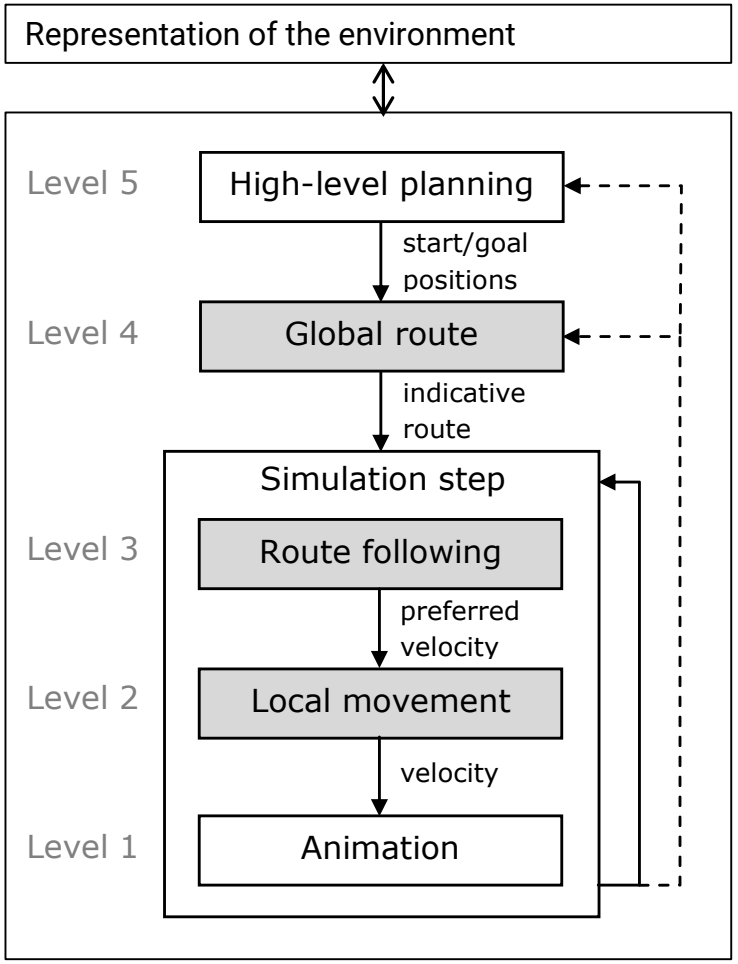


DEMOLITION TIME

The UUCS engine in action

IMPLEMENTATION DETAILS

Crowd simulation in the UUCS framework

Simulation step

- performStep(Δt)
  - For each agent: path following
    - Update pointers along indicative route
    - Update attraction point, preferred velocity
  - For each agent: collision avoidance
    - Compute new velocity vNew
    - Smoothen vNew (optional)
    - Compute collision forces F (optional)
  - For each agent
    - Update velocity: v := vNew + Δt · F/mass
    - Update position: p := p + Δt · v
  - Update nearest-neighbor data structure

(There are actually many more **substeps**)

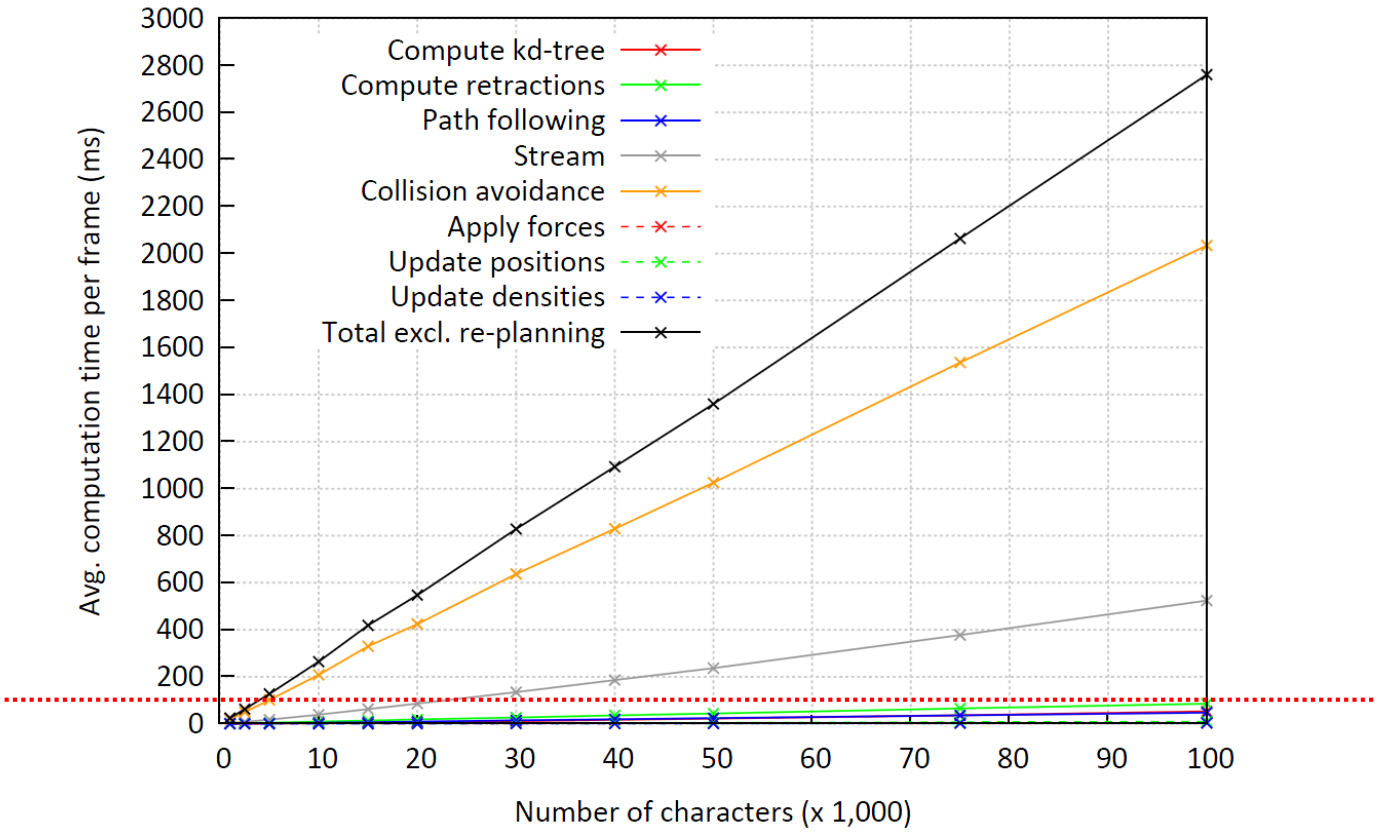
Why separate loops?

→ **Order** of agents does not matter

→ Agents are independent, each loop can be **parallellized**

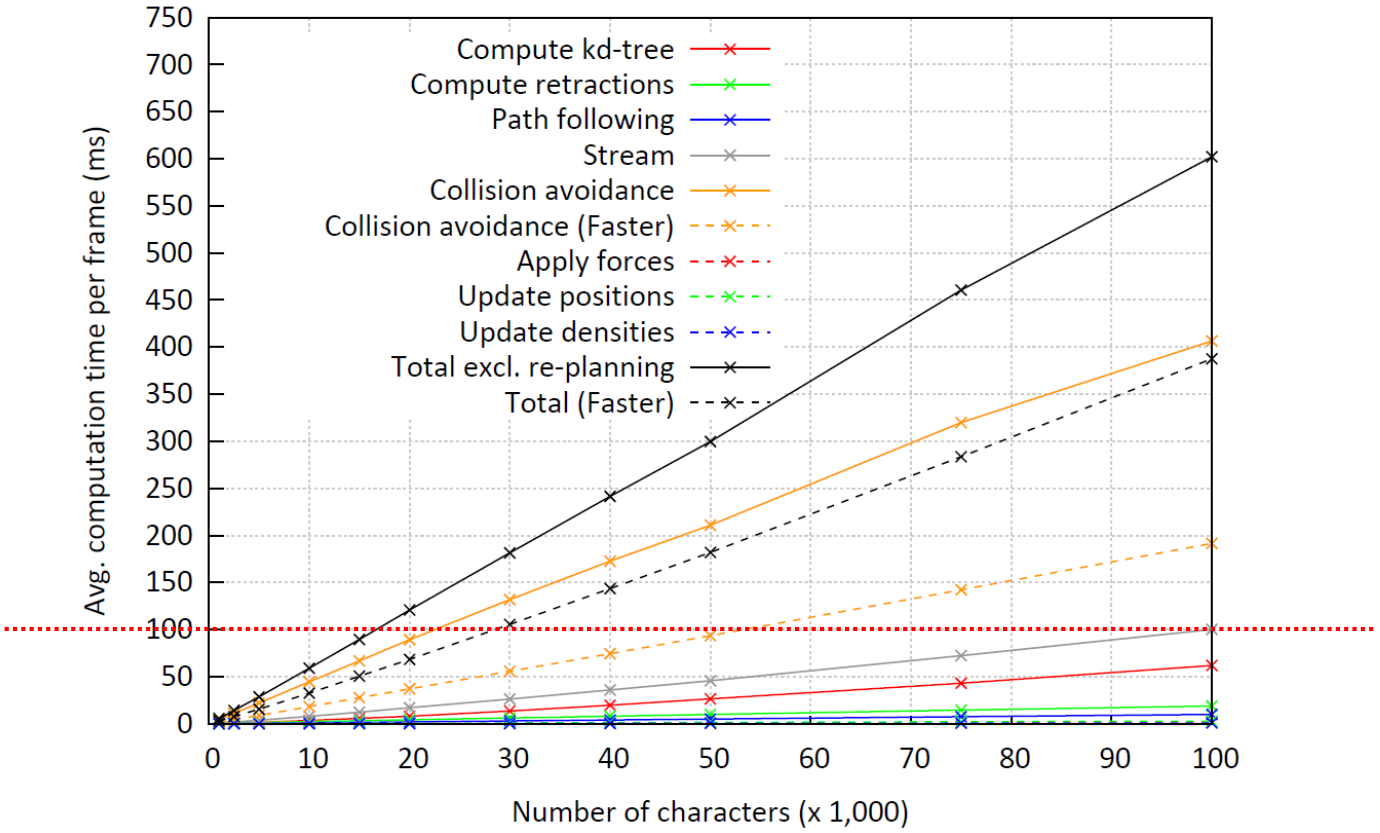
Performance (without visualization)

- 1 thread (2015)



Performance (without visualization)

- 8 threads: 4 cores (2015)



Assignments

Collision avoidance 1 / 2

- Algorithm
  - Focus on Optimal Reciprocal Collision Avoidance (ORCA)
  - Appears to be the most expense part of UUCS
- Code
  - src/Simulation/CollisionAvoidance/CollisionAvoidance_RVO.cpp
  - 444 lines of code
  - Code includes solving a linear program
- Literature
  - Paper: http://gamma.cs.unc.edu/RVO/icra2008.pdf
  - GPU tips: https://arxiv.org/abs/1908.10107
  - LP GPU implementation: https://rgb-lp-docs.readthedocs.io/en/latest/

Collision avoidance 2 / 2

- Goal
  - Optimize CPU code, or
  - Convert to GPU implementation
- Performance criterion
  - Relative difference in total running time of collision avoidance during 60s (600 frames) in city environment with 25K agents

KD-tree 1 / 2

- Algorithm
  - NanoFlann
  - Computes and queries a nearest neighbors KD-tree
- Code
  - src/external/nanoflann/nanoflann.hpp
  - 1946 lines
  - Optimized templated C++ code
- Literature
  - https://github.com/jlblancoc/nanoflann

KD-tree 2 / 2

- Goal
  - Optimize C++ code
- Performance criterion
  - Relative difference in total running time of building the KD-tree and all nearest neighbor queries during 60s (600 frames) in city environment with 25K agents

UUCS 1 / 2

- Algorithm
  - UUCS codebase
- Code
  - Mainly src/Simulation/*
  - 10K lines?
- Literature
  - Framework: https://www.staff.science.uu.nl/~gerae101/UU_crowd_simulation_publications_framework.html
  - PhD thesis: https://www.staff.science.uu.nl/~gerae101/pdf/PhD_Thesis_Wouter_van_Toll_Navigation_for_characters_and_crowds_in_complex_virtual_environments.pdf

UUCS 2 / 2

- Goal
  - Optimize C++ code
- Performance criterion
  - Relative difference in total running time of the whole simulation during 60s (600 frames) in city environment with 25K agents

Prizes

1. Arduino starter kit
2. Arduino starter kit
3. Arduino starter kit

Getting started

- Sign EULA
  - Improvements may be integrated in UUCS
  - IP goes to University so that education and research is secured
  - ucrowds.com/eula
- After signing, you will get access to
  - UUCS library and demo projects
    - https://git.science.uu.nl/UUCS/explicit-corridor-map-framework
- To compile the project
  - Follow the instructions listed in README.md
  - You can get some help

Technical support

- Compilation
  - Geert-Jan Giezeman
  - g.j.giezeman@uu.nl
  - BBG 5.77
  - Please send him an e-mail first
- Weekly visit hour
  - Monday 10.00 - 11.00
  - UtrechtInc, Padualaan 8, Office W125
  - Contact Yiran Zhao
    - yiran@ucrowds.com

Questions

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