UU Crowd Simulation Software: Theory and Implementation

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Summerschool “Multidisciplinary Game Research”

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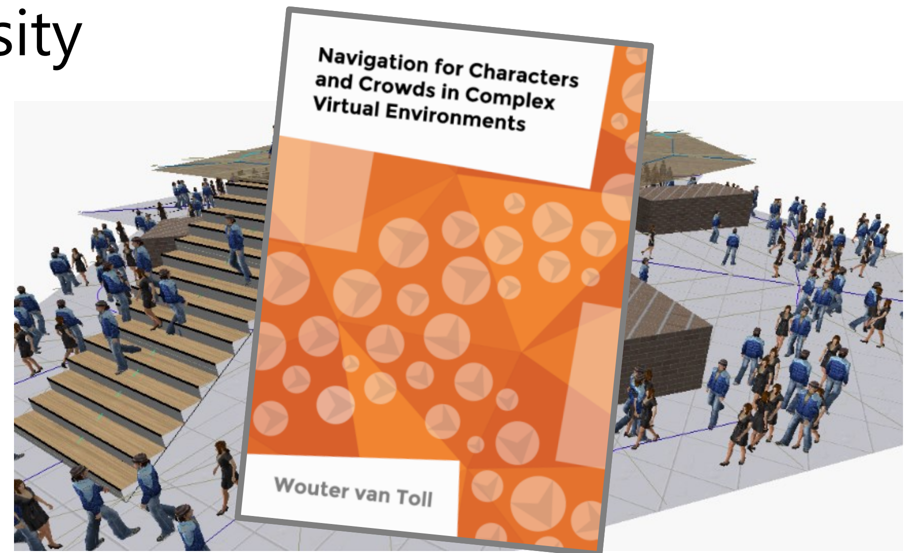
About me

- Education at Utrecht University
  - BSc Computer Science
  - MSc Game and Media Technology
  - PhD: Path planning and crowd simulation
  - Main programmer of our crowd simulation software
- Now: Lecturer at UU
  - Game programming (1st year BSc)
  - Geometric algorithms (MSc)

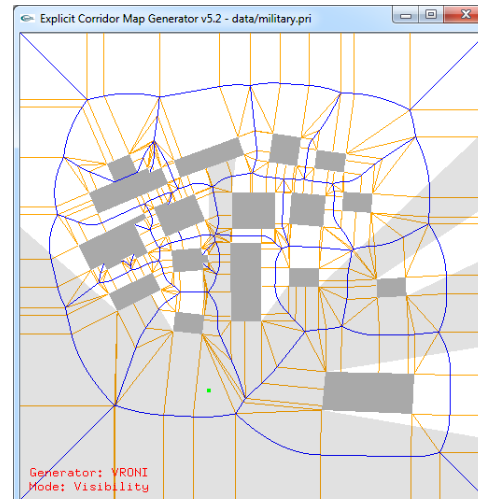


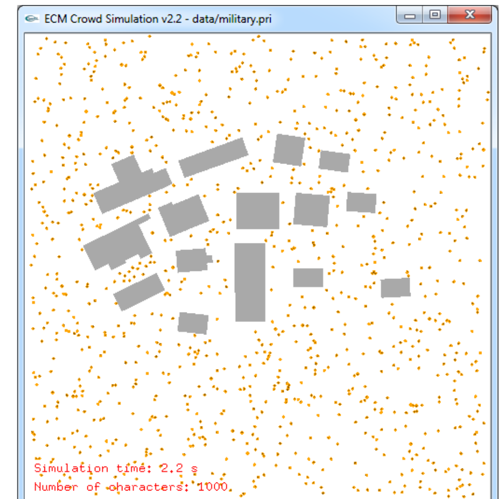
This presentation

- Overview of our theoretical **framework**
  - Five levels of crowd simulation
- Overview of how our **software** works
  - Later, you'll use our Unity3D plugin...
  - ...and you'll know what is happening in the background!

UUCS overview

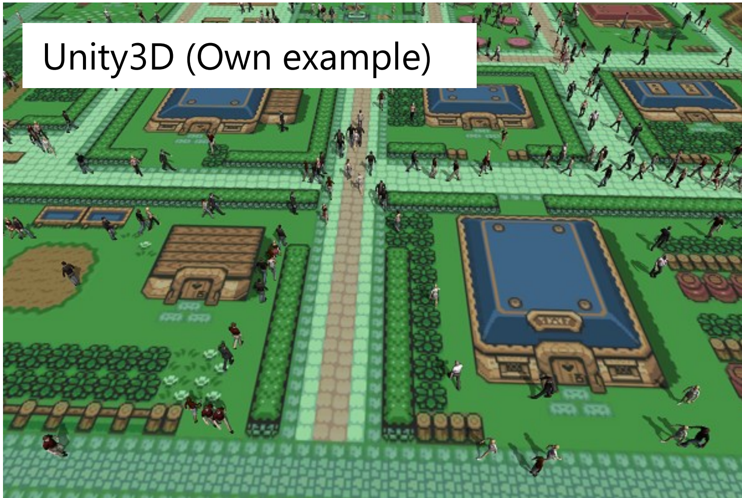
- Software with two main tasks
  - Constructing the ECM **navigation mesh**
  - Simulating crowds in real-time

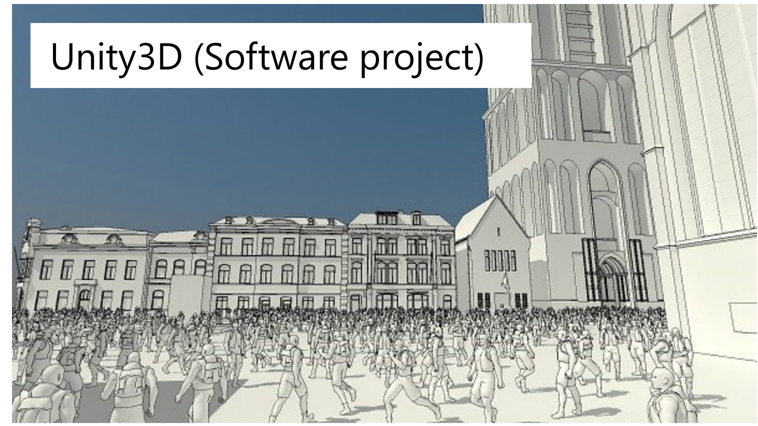


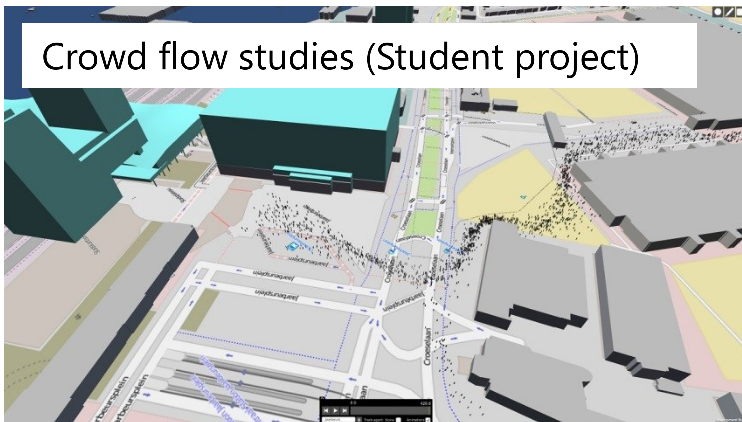


- Written in C++
- API in C
  - DLL can be plugged into other software
  - Unity3D integration: topic of many UU software projects

UUCS examples





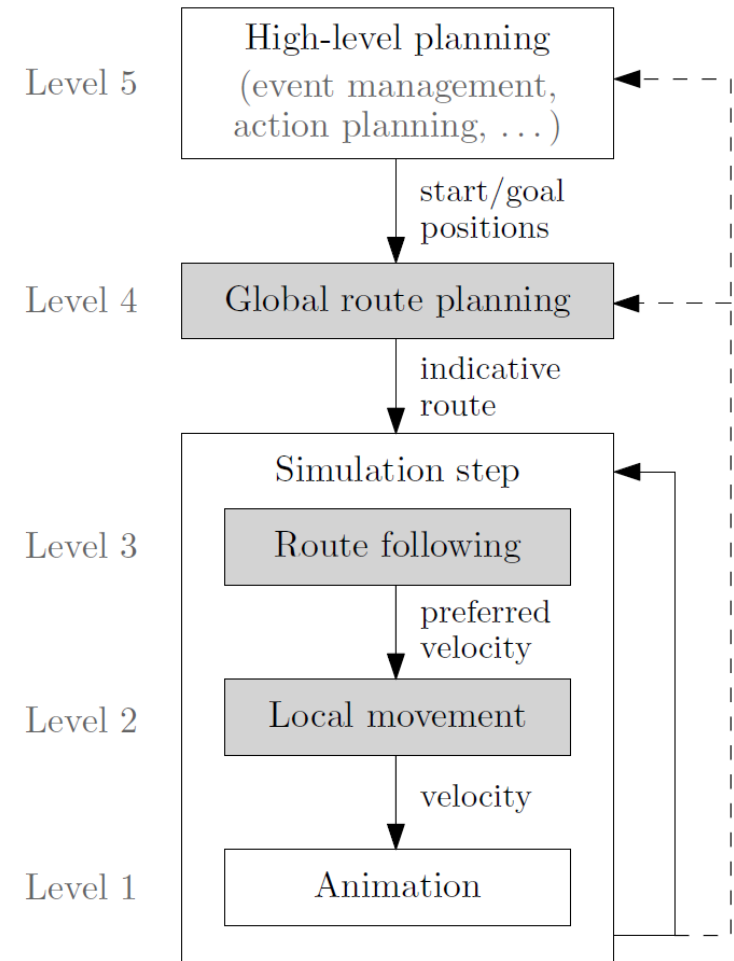


Algorithms in a crowd simulation framework

Theory

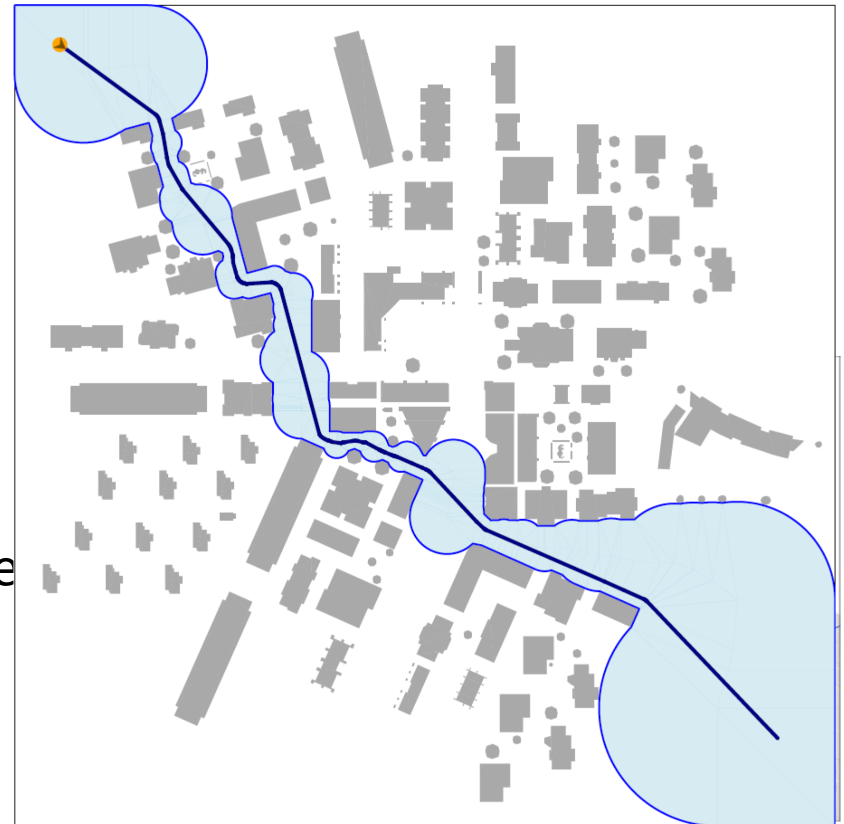
Crowd simulation framework

- Overview paper
  - "Towards Believable Crowds: A Generic Multi-Level Framework for Agent Navigation"
- Our software focuses on levels 4/3/2
  - Geometric components

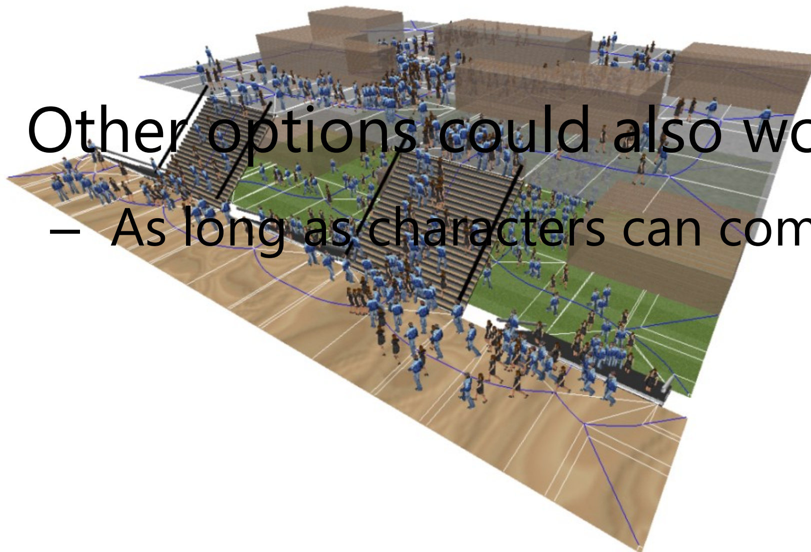


4: Global path planning

- We use the **Explicit Corridor Map**
  - Compact navigation mesh
  - Supports any character radius
  - Multi-layered environments
  - Dynamic updates

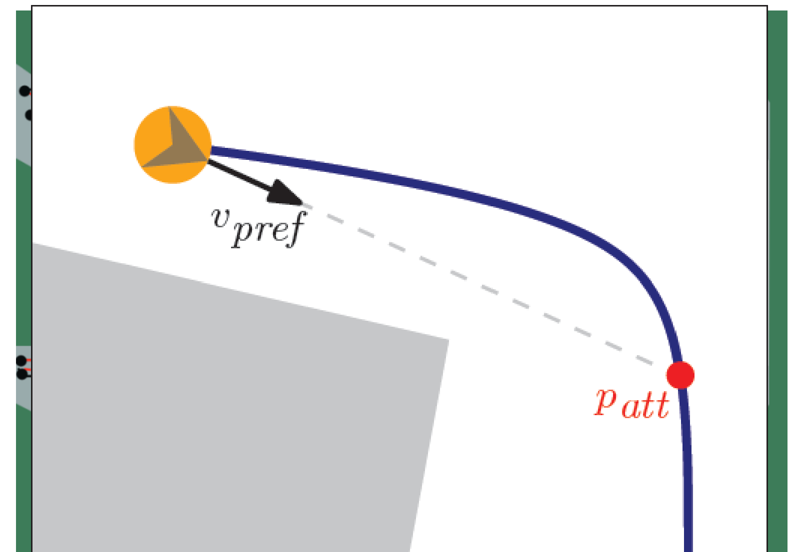


- Other options could also work
  - As long as characters can compute



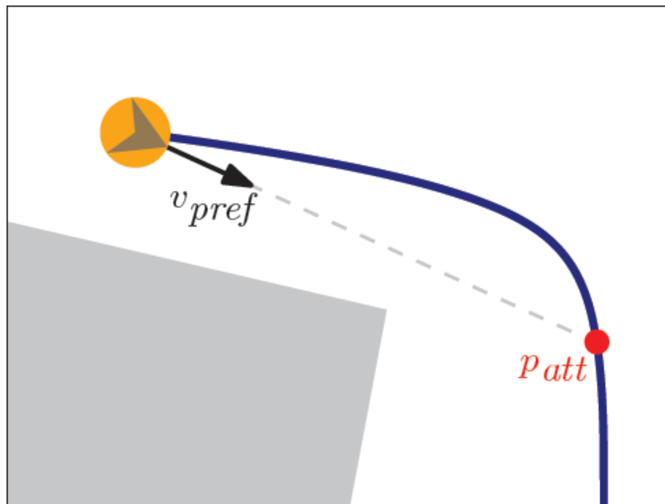
3: Path following

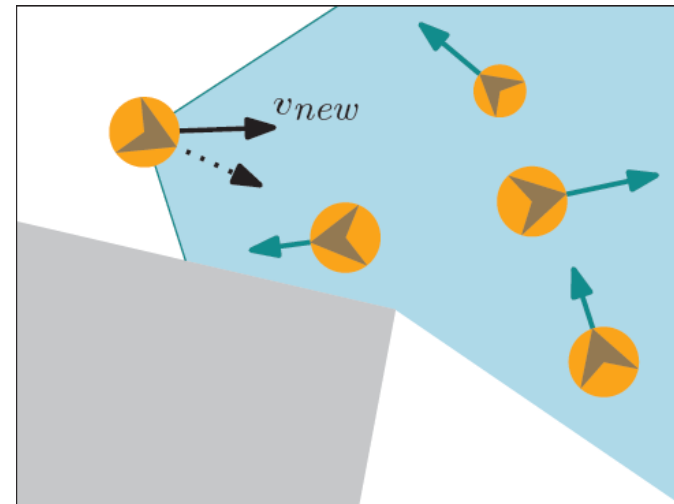
- Smoothly follow a desired path
  - Input: **indicative route**, non-smooth indication of the path
  - In each simulation step, compute an attraction point
  - Leads to a preferred velocity for the next level
- Indicative Route Method (IRM, 2009)
- MIRAN (#7): improvement by Jaklin et al. (2013)
  - Supports weighted regions
  - Better smoothness / shortcut control



2: Local movement

- Roughly move in the preferred direction, while…
  - …avoiding future collisions with other characters
  - …responding to collisions that have already happened
  - …adapting to the surrounding streams of people
  - …maintaining social group behavior
  - …



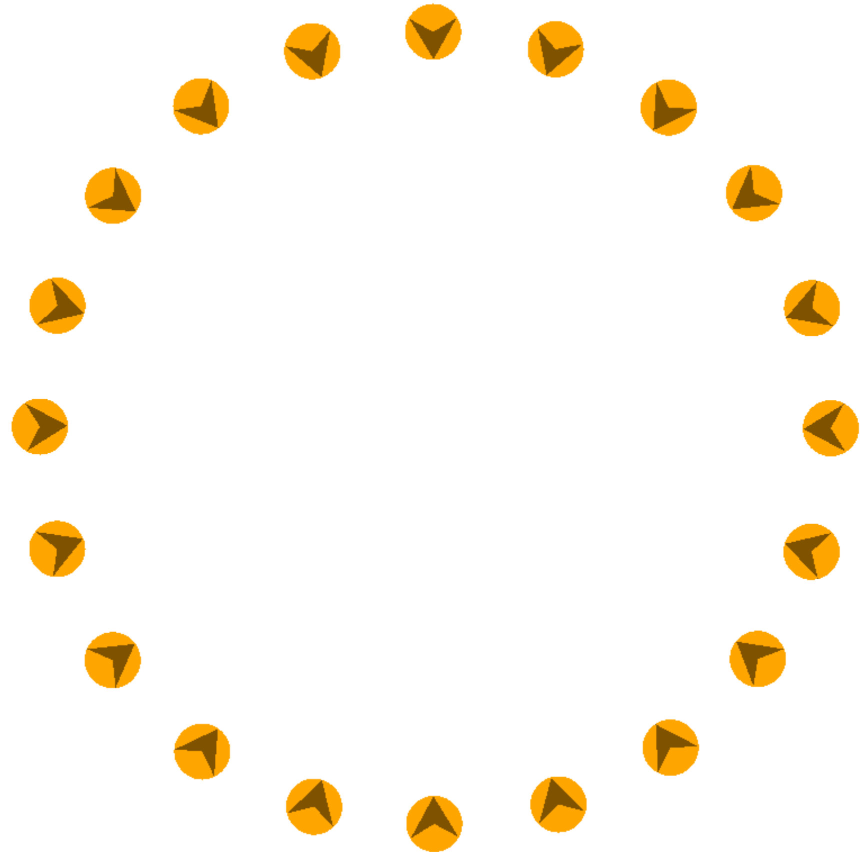


UUCS in action

Demo time

Demos

- ECM
- Single agent
- Crowd
- Circle



Implementation details

Paper vs. Implementation

- It's hard to judge a method in practice
  - Not all parameter settings are described in a paper
  - Lots of details are up to the programmer
  - Some necessary hacks are not mentioned
  - **Small changes can have huge impacts**

Simulation step

- Core of the crowd simulation engine
- performStep(Δt)
  - Increase total time by Δt
  - For each character: path following
    - Update pointers along indicative route (if any)
    - Compute new attraction point, preferred velocity
  - For each character: collision avoidance
    - Compute new velocity **vNew**
    - Smoothen **vNew** (optional)
    - Compute collision forces **F** (optional)
  - For each character
    - Update velocity: $\mathbf{v} := \mathbf{vNew} + \Delta t \cdot \mathbf{F}/\text{mass}$
    - Update position: $\mathbf{p} := \mathbf{p} + \Delta t \cdot \mathbf{v}$
  - Update nearest-neighbor data structure

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

Why separate loops?

→ **Order** of characters does not matter

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

Simulation loop

- Update the simulation per time step: performStep(Δt)

- Possible approach: do as many steps as possible
  - Use time between frames as step size
  - Use FPS to measure efficiency

Is this a good idea?

- We use a fixed time step (0.1 s)
  - Use computation time to measure efficiency
  - Behavior does not depend on the framerate
  - Fast-forward by calling performStep() more/less often
  - Visualization framerate can be much higher

Plug-in / API

- "Black box" with basic entry functions
  - Compute navigation mesh
  - Add/Remove character
  - Plan a path for a character
  - Set character parameters
  - Advance the simulation by a single step
  - ...
- Written in C
  - Unity3D: C# wrapper around the API

Closing comments

Summary

- Crowd simulation is a complex problem
- We split it into easier subproblems (levels)
  - E.g. route planning, route following, local movement
  - Many possible algorithms for each level
- Implementation in C++
  - ECM navigation mesh
  - Real-time crowd simulation
  - API in C for integration into Unity3D

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