A cellular atomaton in geographical space

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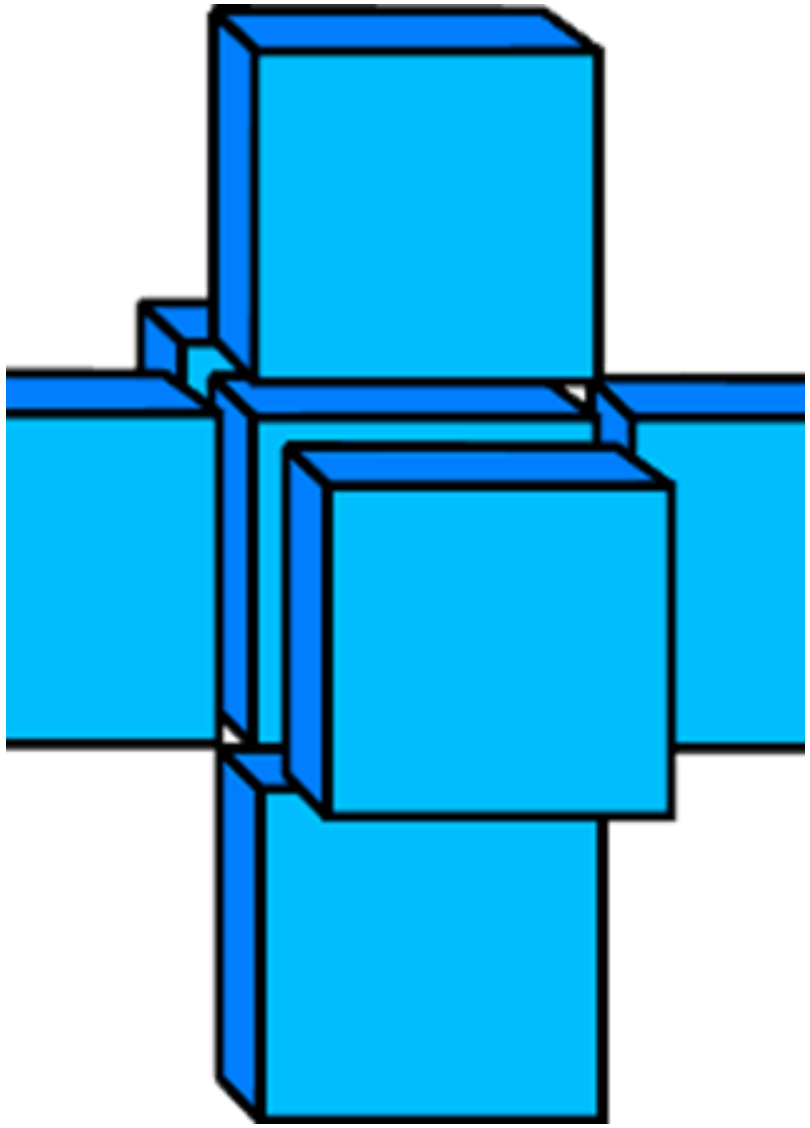
Agenda

- Introduction
- Cellular automata, theory
- CA, practical element, voxel intro, then BREAK
- Voxels, grids and smart voxels
- Example: navy ship
- Example: topology at work



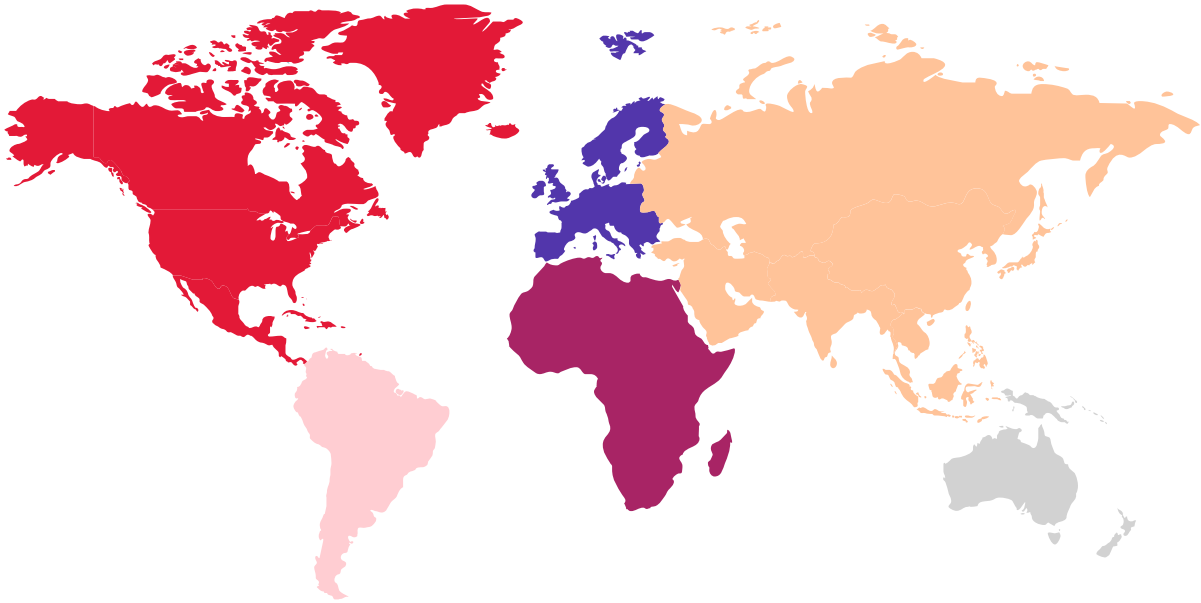
CGI and Geo-ICT

All about location, spatial data and innovation

Consultancy
High Consultancy and vision building.

Integration
Integrating location into client applications.

Innovation
3D, positioning, location based, gaming, AR



Partners
Esri, Smallworld, Hexagon, IQGeo

Science and research
Universities, research, postdocs, papers, students.

Cross Industry
Utilities, government, defense, infrastructure, oil, telecom

Location based, spatial and time related, data is always at the core of operations, assets, planning, simulation and governmental processes. CGI understands this with over 800 specialists.

1985-1986
Board Member
Landmeetkundig
Gezelschap Snellius

Robert Voûte

Vice President Consulting Expert – GEO

1989 MSc Geodesy TU Delft

1990 Military Service, platoon commander, reserve Major in Army

1991 CGI Current role VP Consulting

2015 Guest researcher at TU Delft

2015 Guest lecturer at American University in Cairo

2017 Member of the board of Geobusiness Nederland

2018 Member of NCG committee Basisgegevens

2019 Member of field committee MGI master at Wageningen University and Research

2019 Member of the Professional Advisory Board for the Master's Programme Geo-information Science and Earth Observation at University of Twente

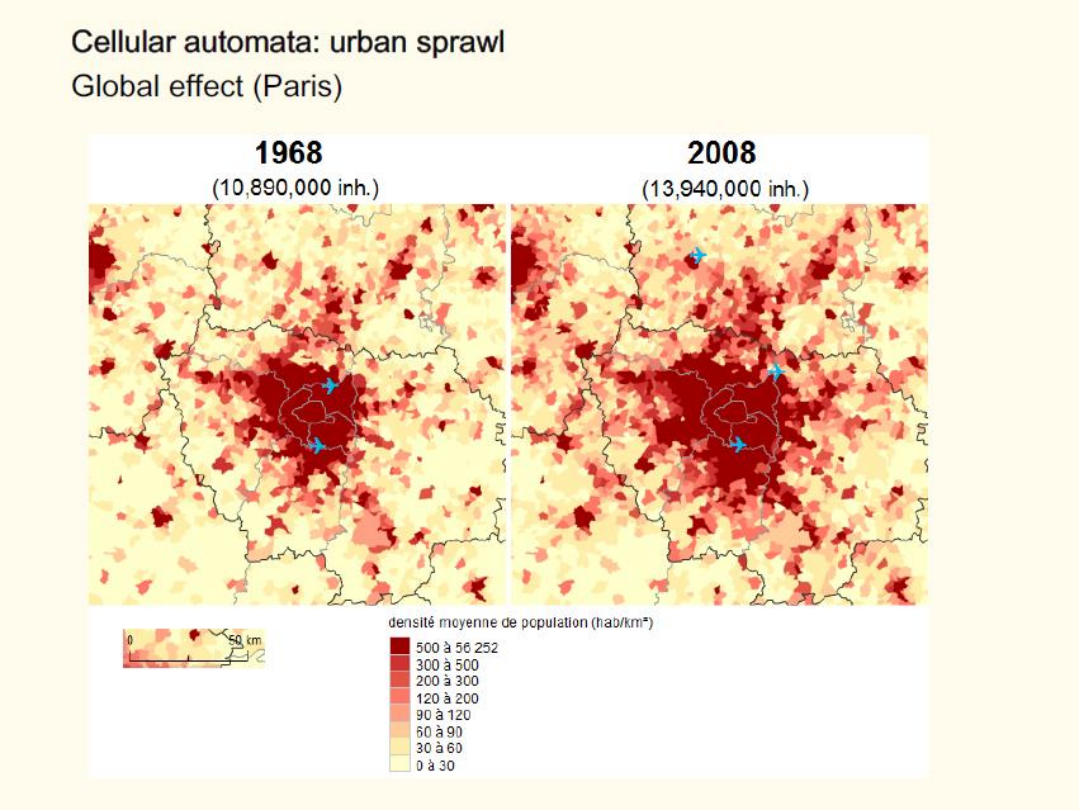
Research done: Indoor 3D mapping, Indoor 3D localization, high precision surveying with drones

Cellular automata, theory

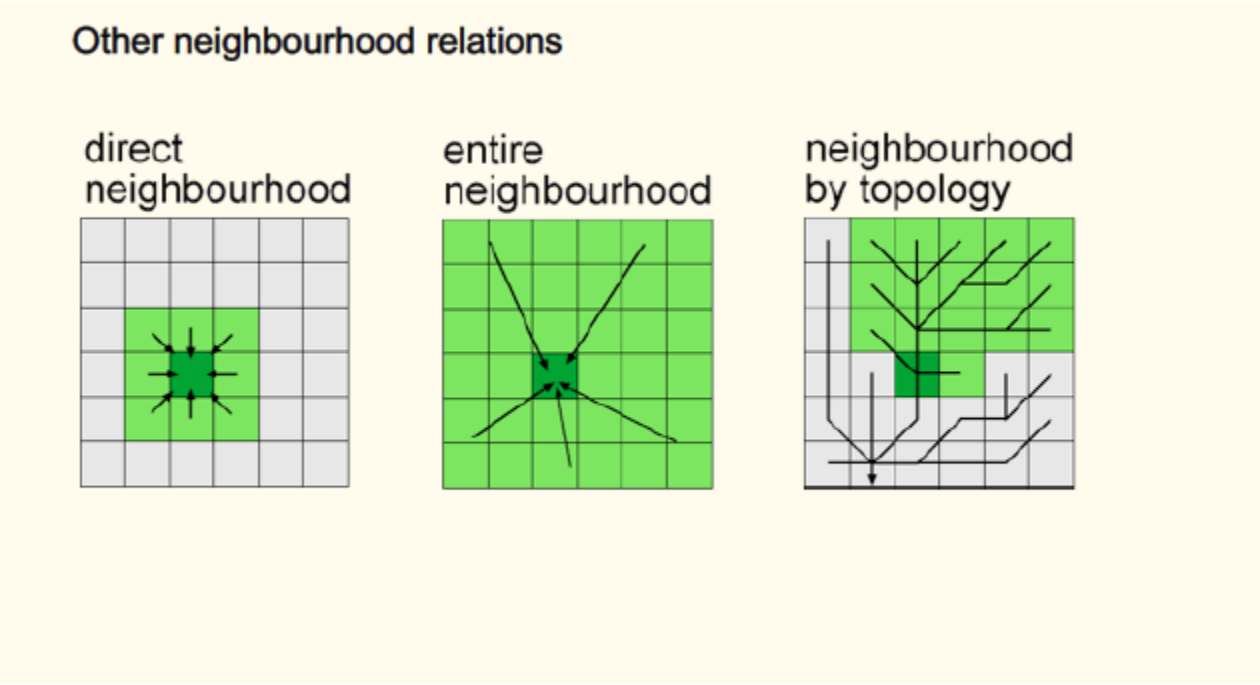
A cellular automaton (CA) is a collection of cells arranged in a grid of specified shape, such that each cell changes state as a function of time, according to a defined set of rules driven by the states of neighboring cells. CAs have been suggested for possible use in public key cryptography, as well as for applications in geography, anthropology, political science, sociology and physics, among others.

Mostly used for simulations in geography

for urban planning, spreading natural phenomena



Neighbouring



Grids: 2D, 3D, DGGS

2D

- Triagles
- Rectangles
- Hexagons, etc.
- DGGS, Discrete Global Grid System

3D

- All of the above

But also 1D

Each cell in the grid has a state (or more) and it is all about adjacency.

Do it yourself CA, The Game of Live by James Conway, 1970

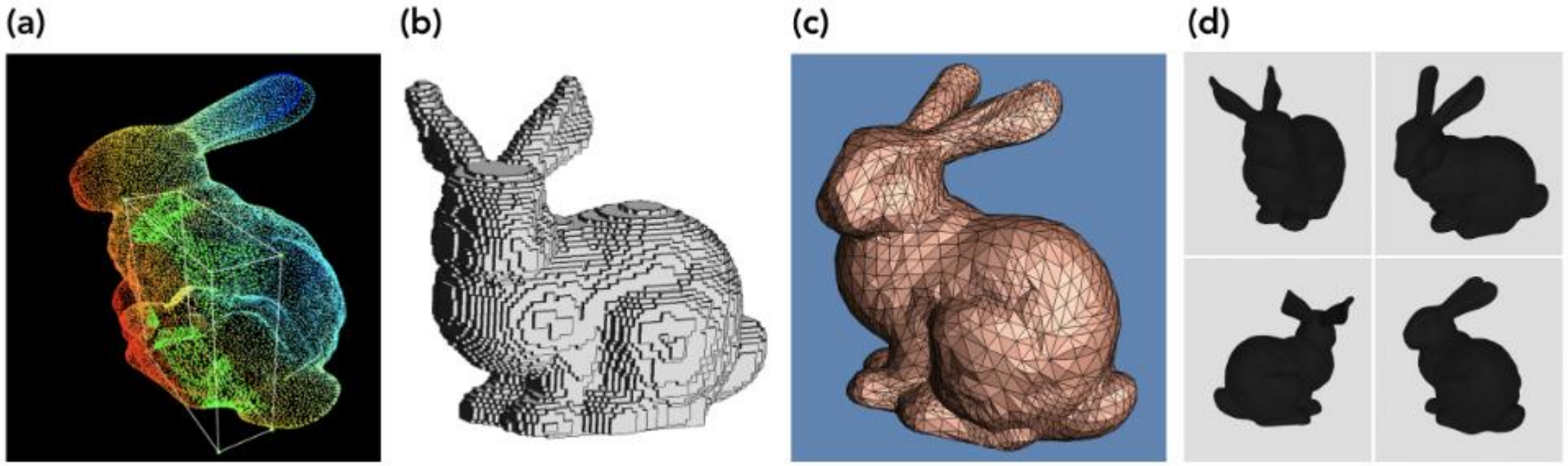
Each cell lives in a square in a rectangular grid. A cell can either be dead or alive (alive cells are coloured blue in our demo). Before you start the game, you need to provide an initial state. You can do this in the above example by clicking on squares, or by picking a preset from the dropdown menu.

The game is now ready to begin, and this involves advancing through time one step at a time. A cell's fate depends on the state of its 8 closest neighbours (our grid utilises wrapping, meaning a cell on the far left is thought of as a neighbour of a cell on the far right, and the same principle applies at the top and bottom).

- If a cell is alive, and 2 or 3 of it's neighbours are also alive, the cell remains alive.
- If a cell is alive and it has more than 3 alive neighbours, it dies of overcrowding.
- If a cell is alive and it has fewer than 2 alive neighbours, it dies of loneliness.
- If a cell is dead and it has exactly 3 neighbours it becomes alive again.

Voxels, theory

A **voxel** is a three-dimensional counterpart to a pixel. It represents a value on a regular grid in a three-dimensional space. Voxels are frequently used in the visualization and analysis of medical and scientific data (e.g. geographic information systems (GIS)).[1]



Voxels, can they be used as a CA?

3D Cellular Automata are extensions of the more common 1D Cellular Automata and 2D Cellular Automata into the third dimension. Rather than just checking neighbor cells in the X and Y directions, the Z direction is also included.

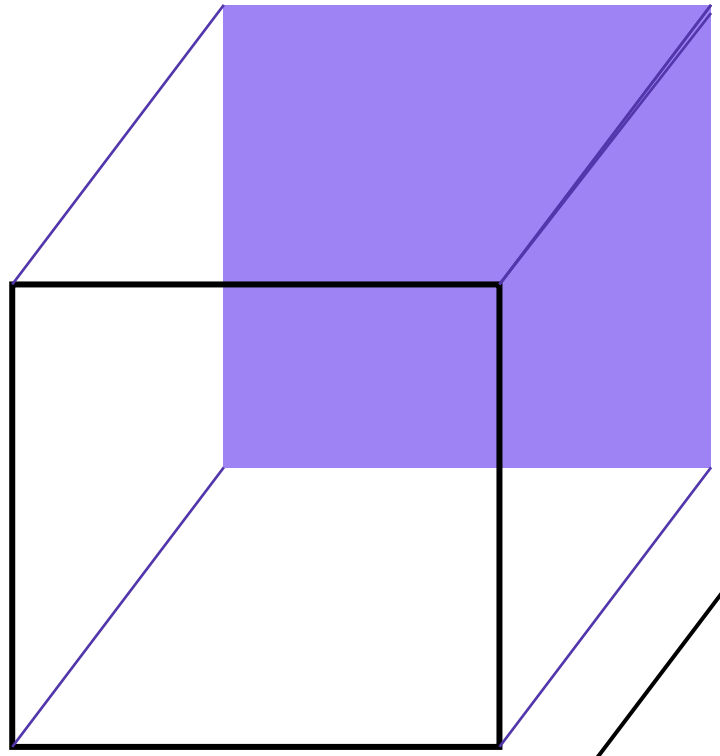
Break

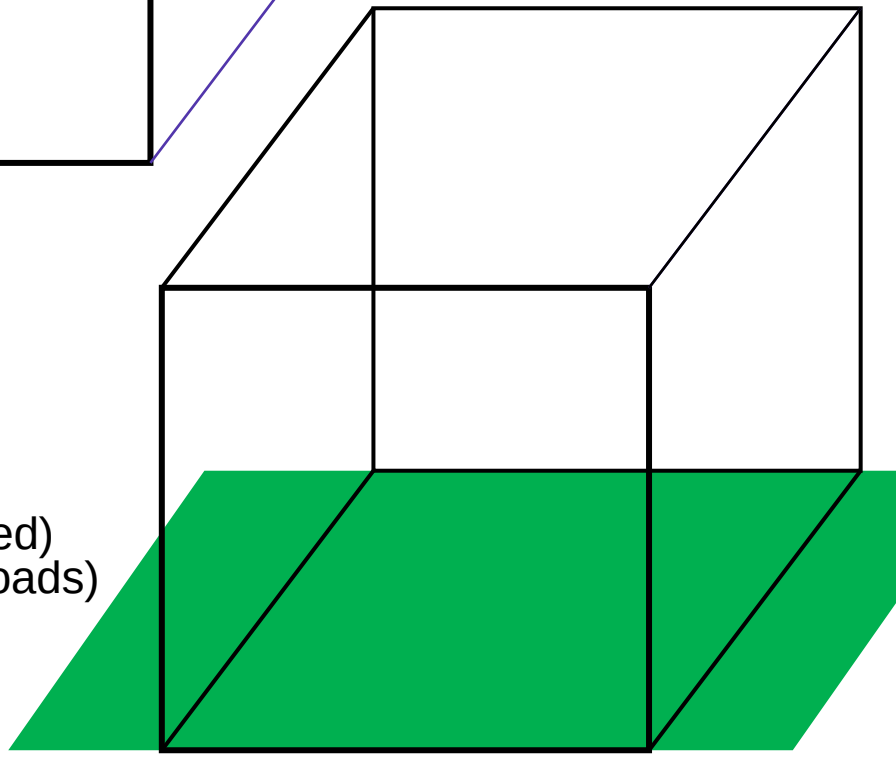
Smart Voxels

3D Cellular (almost-)automaton

But with additional optional behaviour:

- Standard 6 neighbours
- Can be partially “filled”
- Directional
- Flow
- Can have multiple attributes
- So the same voxel can have many different roles
- It is all about the **size** of the voxels
- Representing a real world.

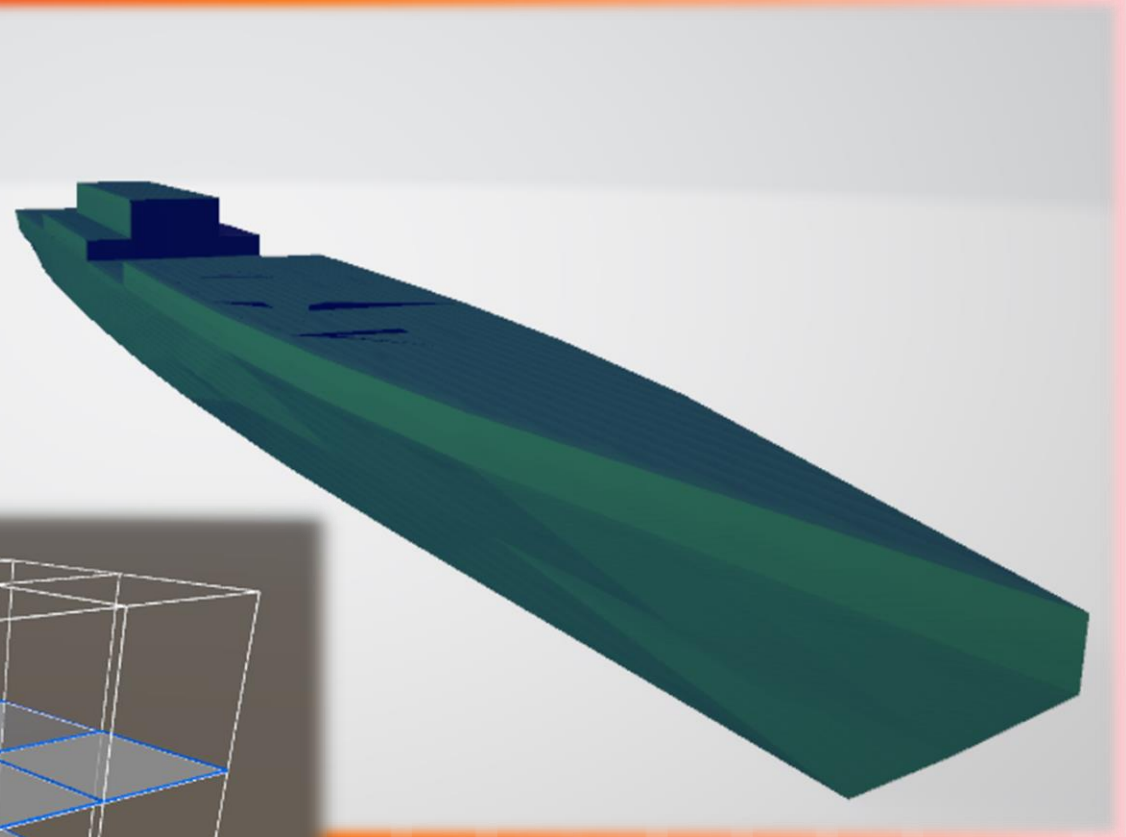


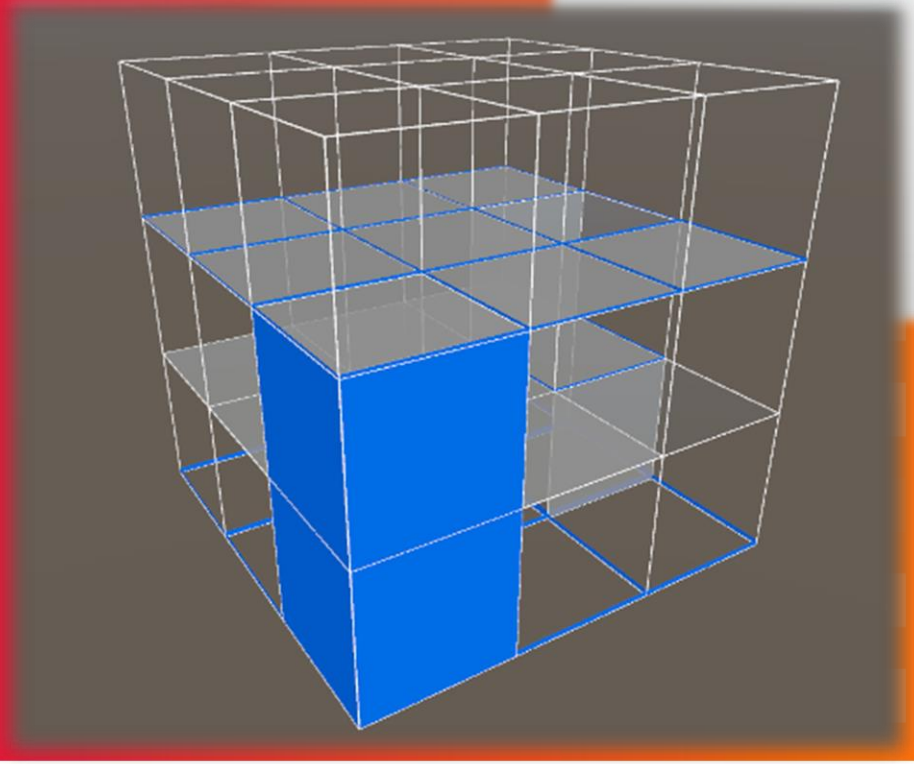


Military example:

- Aircraft flying
- Meteo
- Wind (direction/speed)
- Terrain (obstacles/roads)
- Ballistics
- Sub surface

Determining the effectiveness of cellular automata-models for navy vessel flooding incidents





Toon Meijer

CGI supervisor: Robert Voûte
MGI supervisor: Ron van Lammeren

WAGENINGEN
UNIVERSITY & RESEARCH

CGI

Context

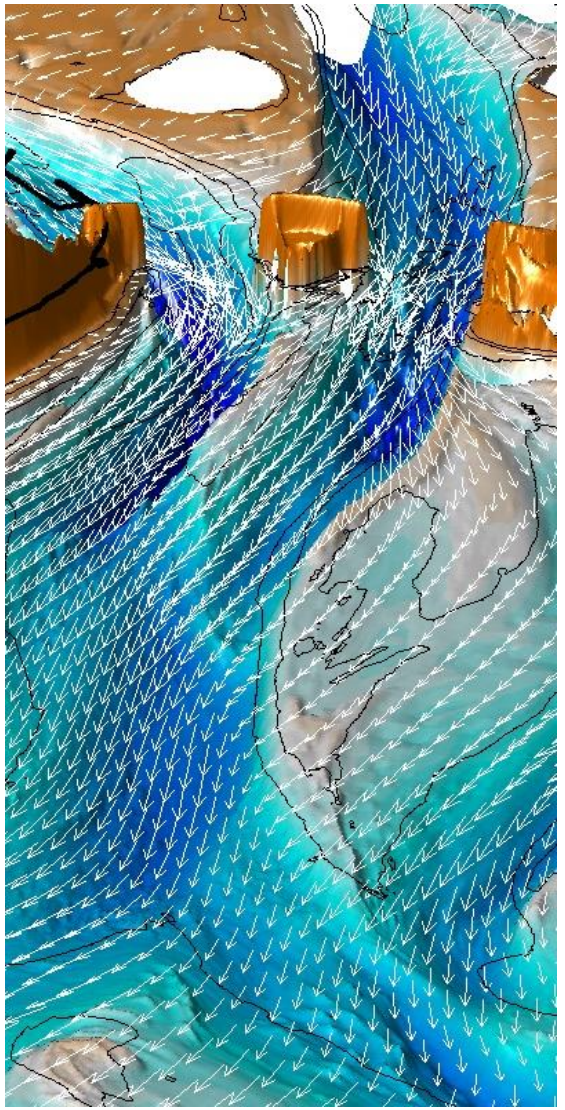
- Spin-off project of larger CGI defence innovation assignment
- “Situational awareness”: ability to perceive & effectively respond to situation
- Real-time incident prediction improves situational awareness

Research aim

“Investigate the feasibility and effectiveness of real-time navy vessel flooding incident simulation using computational models to improve incident predictability.”

State of the art

- Hydrodynamic models: high accuracy but high computational complexity
- Simplified models: lower accuracy but also much lower complexity
- Cellular automata



Research questions

1

What objects in a navy vessel’s interior influence the impact of a flooding incident and must therefore be represented in the cellular automata model?

2

How will the flooding model function within the cellular automata navy vessel model?

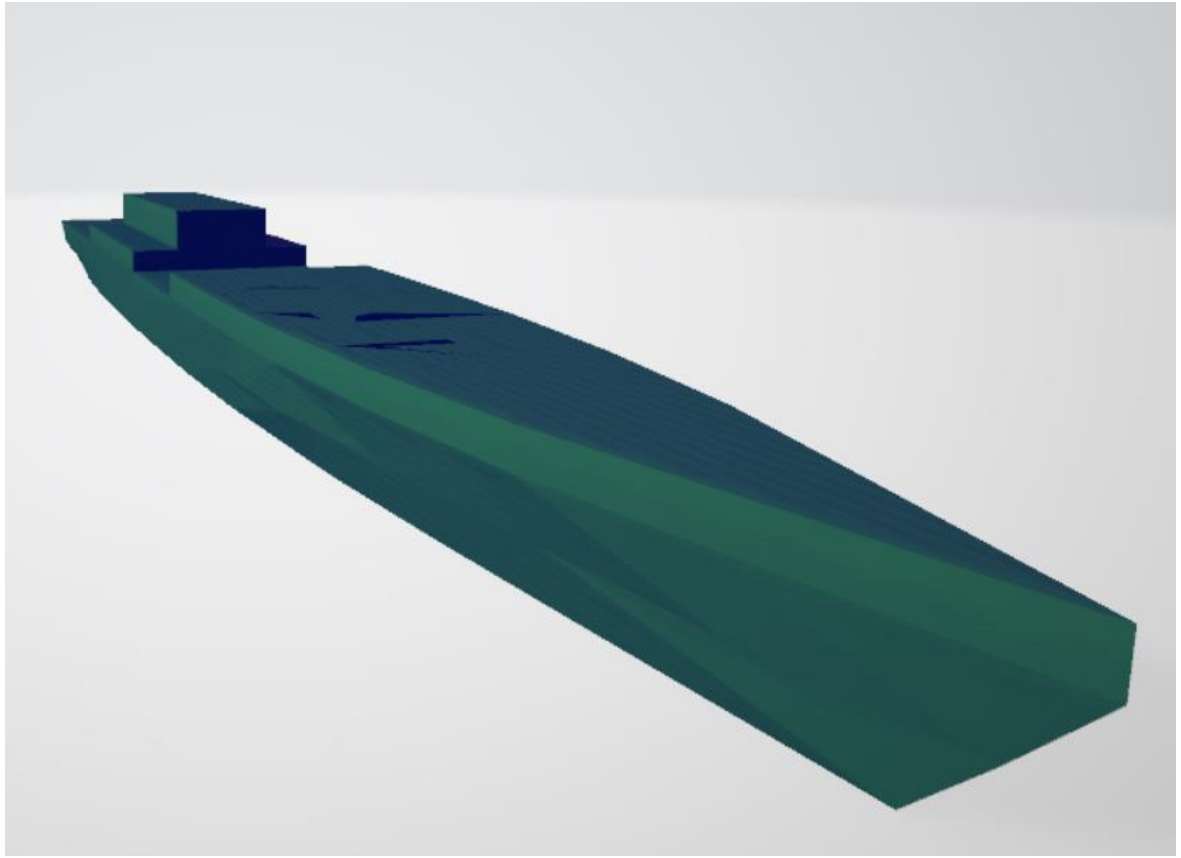
3

What aspects influence the accuracy of the created cellular automata and flooding model in simulating the incident?

RQ1: what objects to be represented in the model?

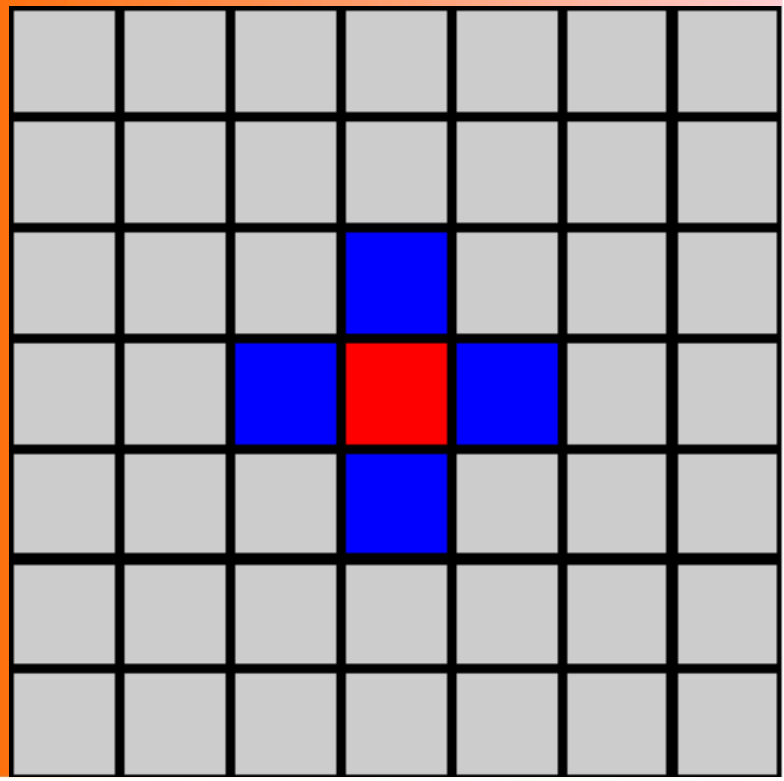
Based on available objects in existing navy vessel model provided by CGI

- Walls
- Doors
- Floors



Cellular automata basics

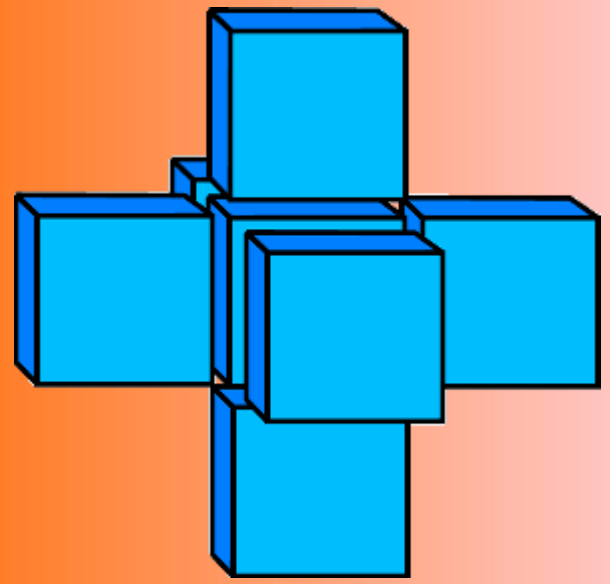
- Regular array of cells updating in discrete time steps
- Each cell only affected by surrounding cells, i.e. its “neighbourhood”
- Rules determine how each cell is affected by its neighbourhood
- Benefits: simpler model rules, lower computational complexity



RQ2: how does the flooding model function?

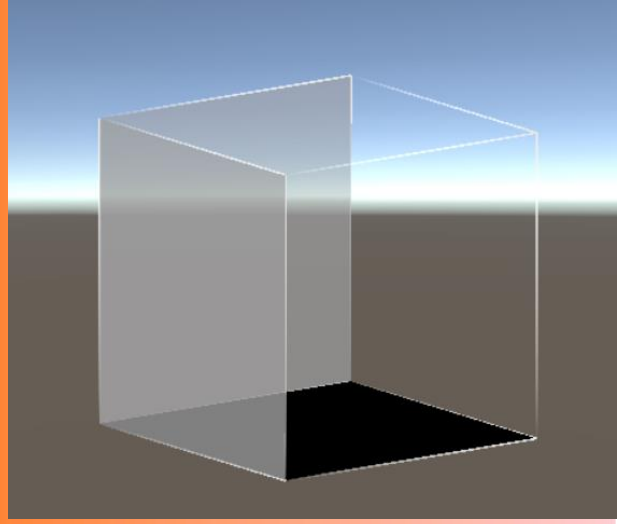
- Chosen for asynchronous cubical cellular automata with von Neumann neighbourhood size
- Water spreading algorithm:

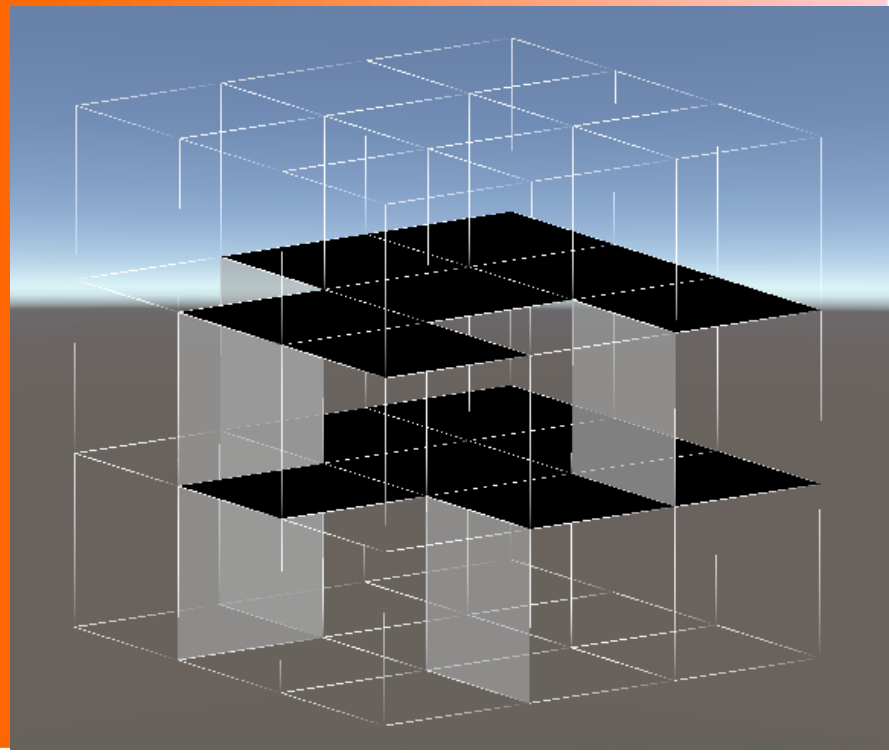
    1. Fill cell below
    2. Average water level between all neighbouring cells at the same level
    3. If current cell is still overfull, fill cell above

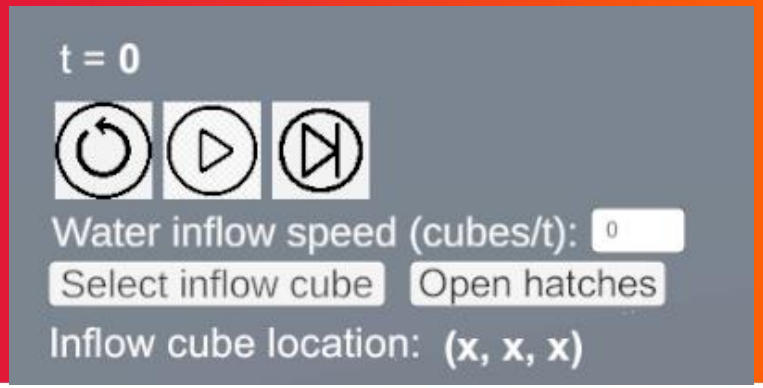


Model building

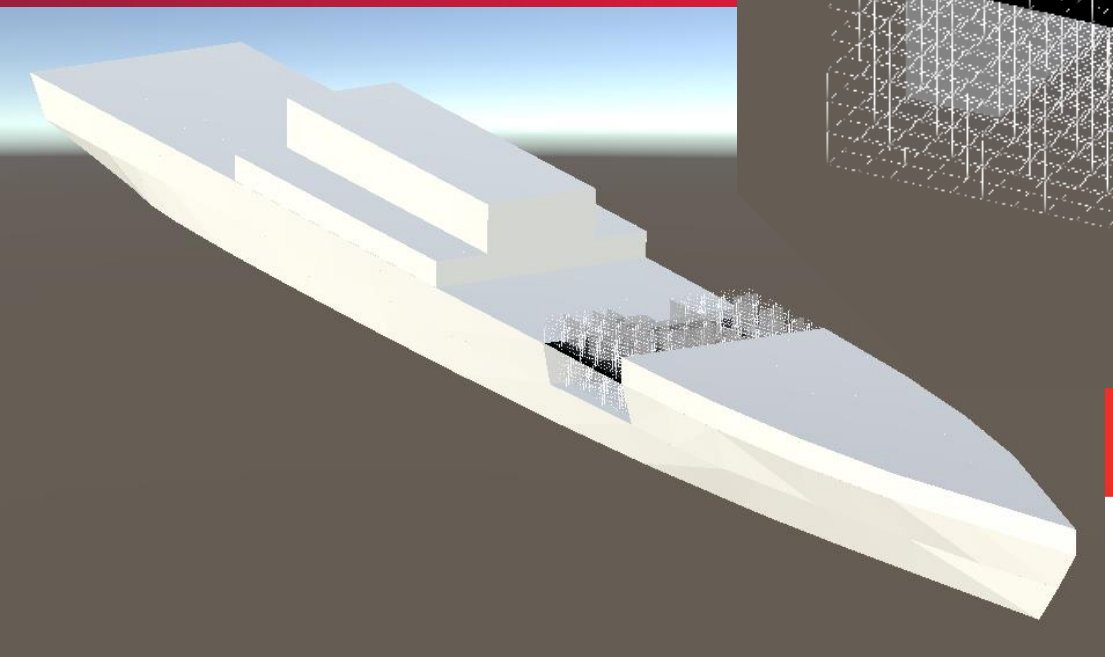
- Building the voxel model in Unity editor
- Creating small user interface for model configuration
- Programming the back-end in C#
- Creating flooding visuals with dynamic shader
- Cube size of 40 cm

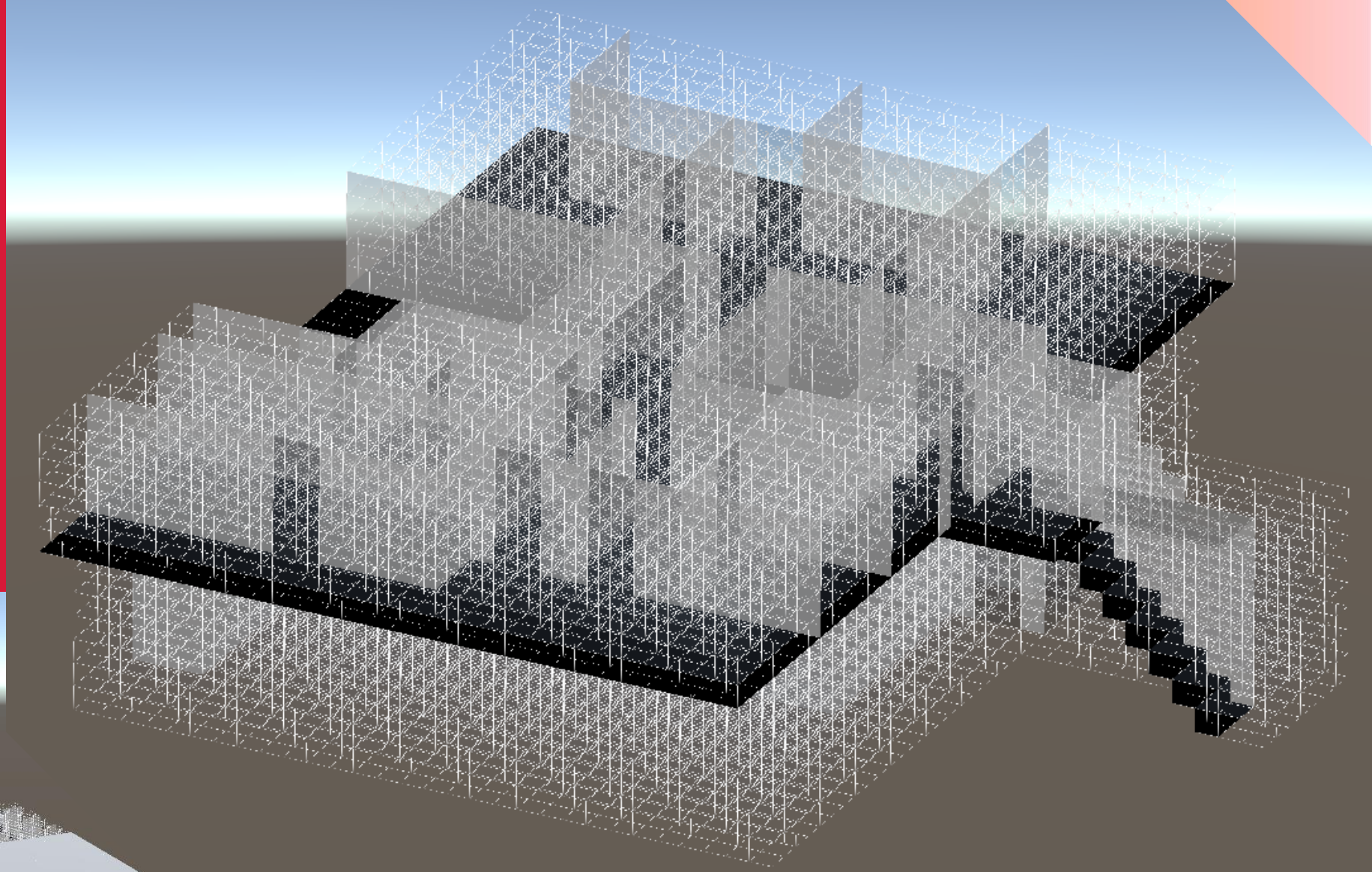






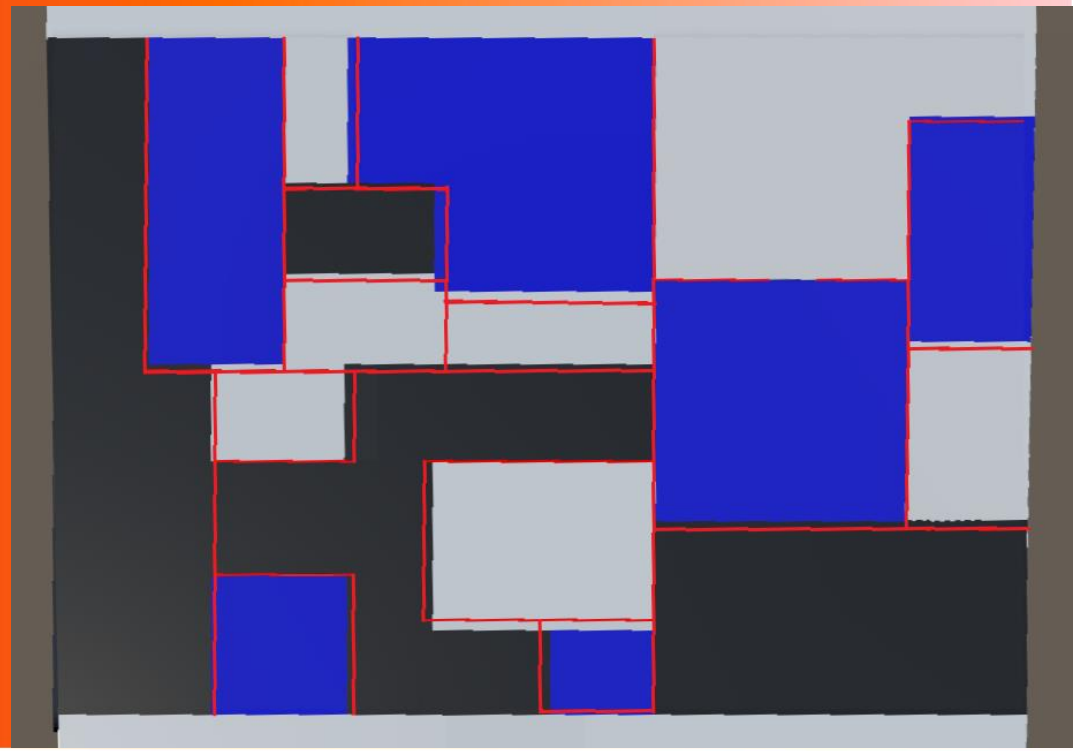
Model building





RQ3: what aspects influence model accuracy?

- Chosen voxel size, determining how closely model represents reality
- Amount of water spreading algorithm runs per time step
- Neighbourhood size



Discussion

- Cellular automata model deviates somewhat from reality but still quite close
- Flooding model is difficult to compare, no other flooding models tested on same space

Recommendations

- Simulate navy vessel wave movement
- Decrease computational complexity by parallel computation, cell merging, more efficient processing outside of Unity
- Experiment with different neighbourhood sizes
- Benchmark models against existing models

Conclusion

- Successfully developed functioning CA flooding simulation
- Most important objects are represented
- Plenty of room for improvement

1D CA’s in Dutch Rail

CGI projects at ProRail

Schema WebApplicatie | Nightly

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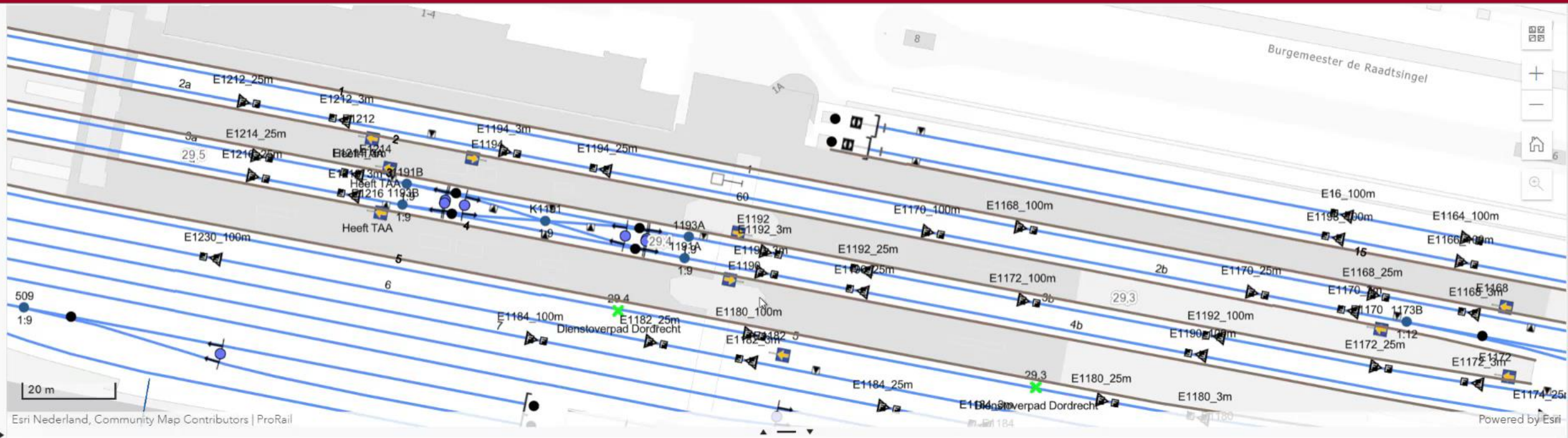
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Esri Nederland, Community Map Contributors | ProRail
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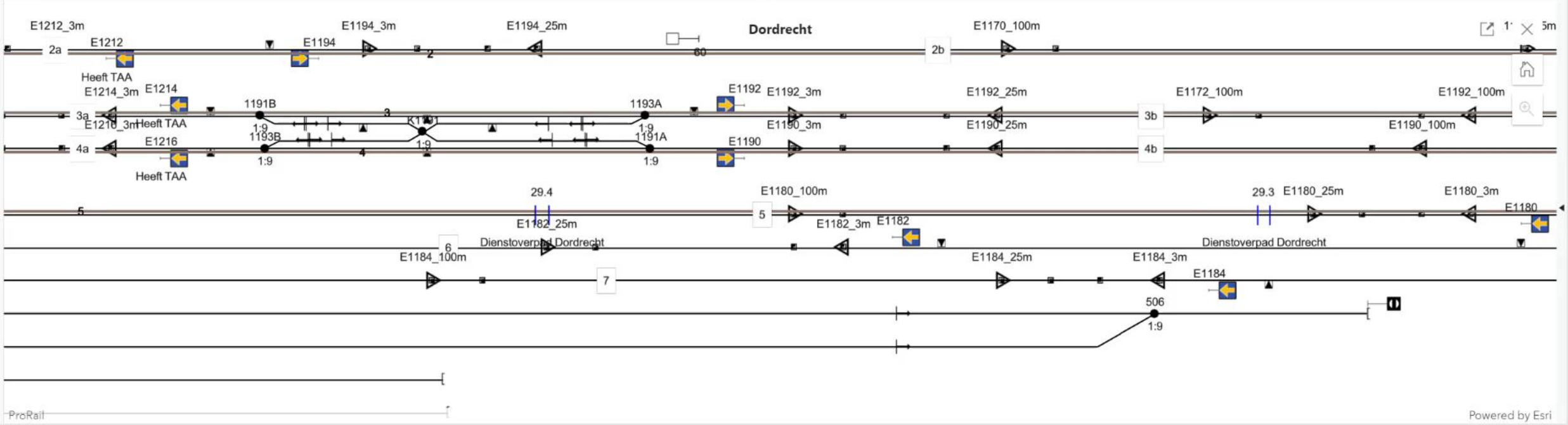
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Any questions?