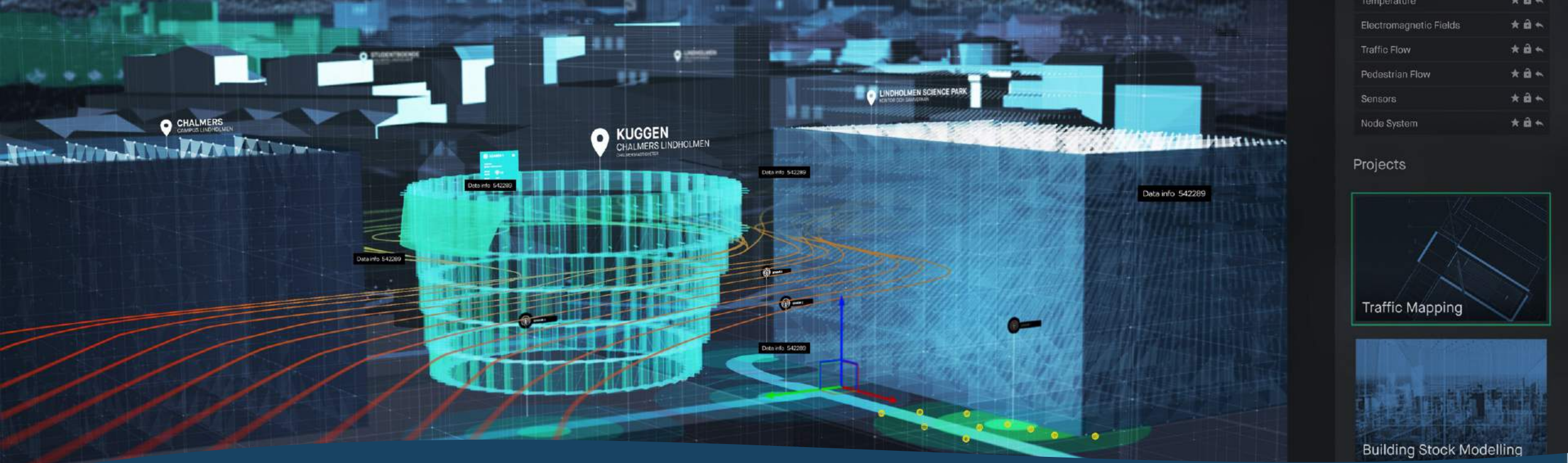


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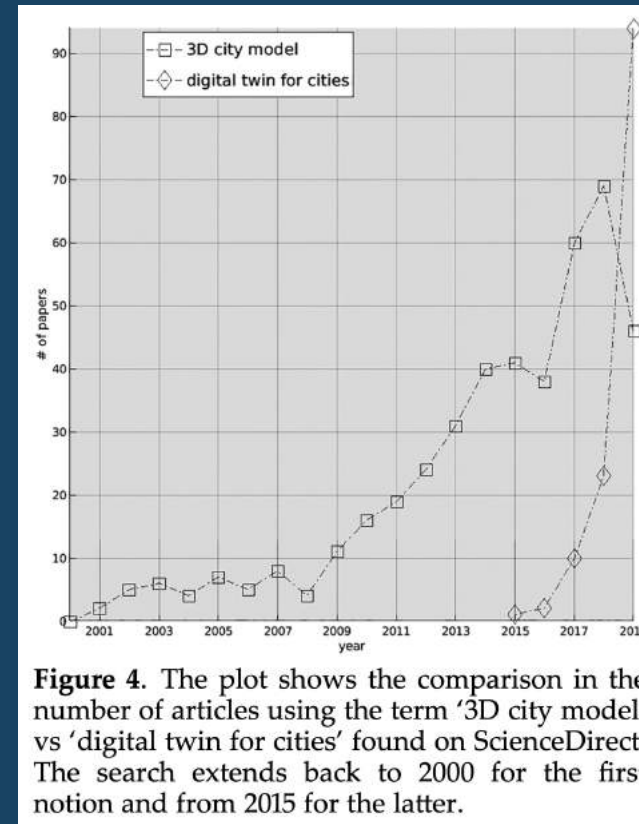
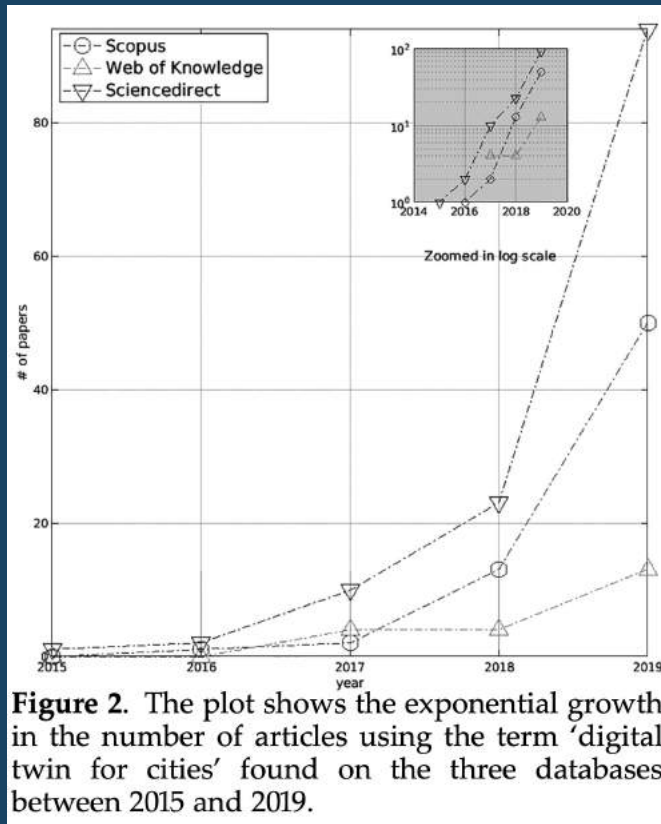
Presented by Anders Logg



What is a Digital Twin?

- Concept originates from the manufacturing industry (early 2000s)
- Digital twins for cities gained momentum in the 2010s
- The concept has exploded since ca 2016 in the built environment
- Encompassing technologies and concepts such as GIS, 3D city models, BIM, smart cities, IoT

Exponential growth of Digital Twin Cities



Ketzler et al. Digital Twins for Cities:
- A State of the Art Review.
Built Environment 2020

The Digital Twin definition

- *[A Digital Twin is] an **integrated** multi-physics, multi-scale, probabilistic **simulation** of a complex product [that] uses the best available physical models, sensor updates, etc.*

Glaessgen and Stargel (2012)

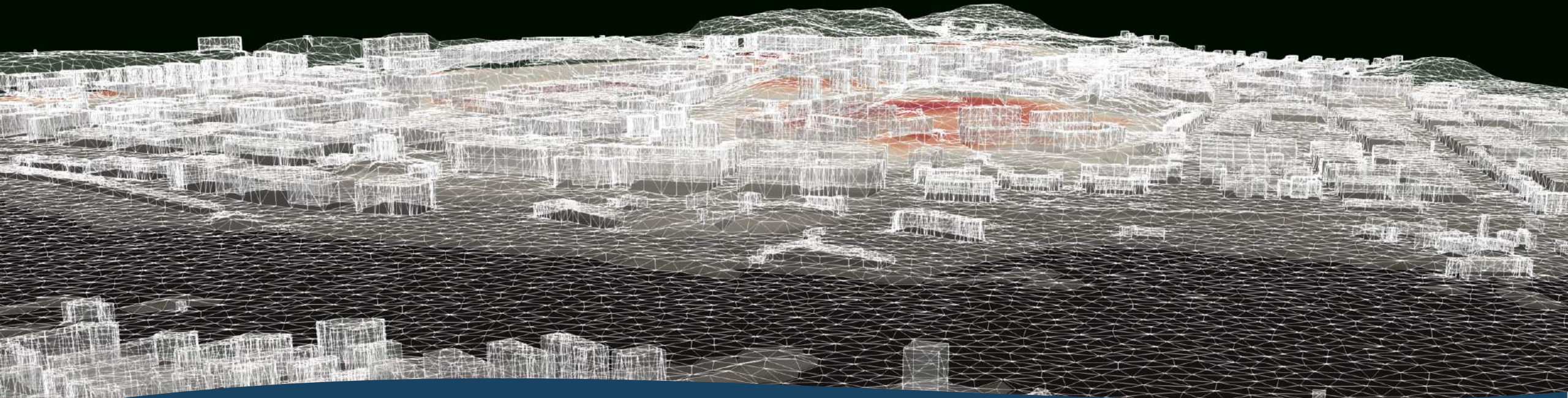
- *[A Digital Twin] should be based on **3D city models**, containing objects with geometric and semantic information; it should contain **real-time sensor data**; and it should integrate a variety of **analyses** and **simulations** to be able to make the best design, planning and intervention decisions.*

Stoter et al. (2021)

Defining characteristics of Digital Twins

- **Realistic** – The digital twin is a realistic 4-dimensional (in both space and time) visual and acoustic experience of the physical twin
- **Interactive** – The digital twin is intuitive, accessible, and supports multi-user interaction
- **Simulated** – The digital twin is a simulation, based on a mathematical model of the physical twin
- **Integrated** – The digital twin is continuously synchronized with the physical twin
- **Scalable** – The digital twin is open-ended, scalable from the building to the district to the city level
- **Open** – The digital twin is driven by open data and models

Ketzler et al. (2020)



Our main challenges are related to data

- **Ownership** - across organisations
- **Quality** - across disciplines
- **Sustainability** - across time

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Centre partners



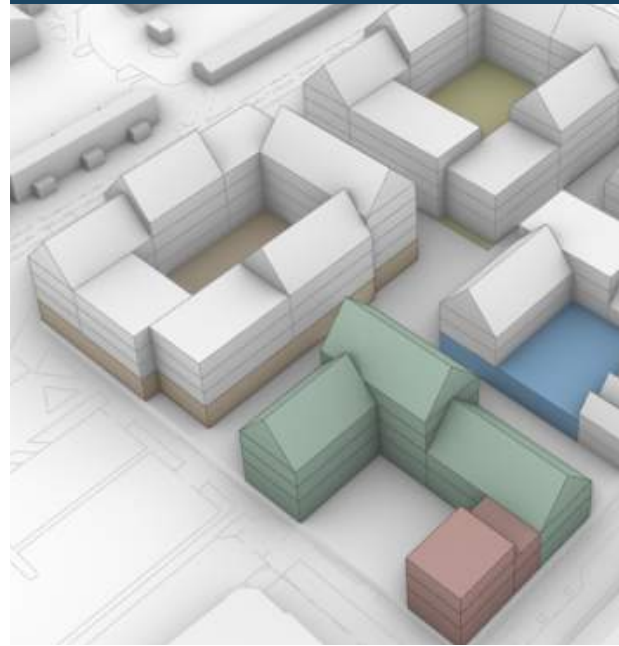
RA0 - Digital Twin Platform



RA1 – Urban Planning & Design



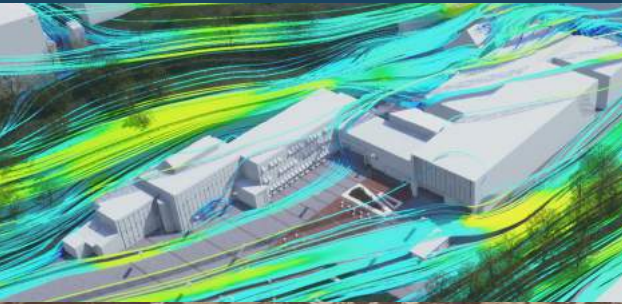
RA2 – Arch. & Structural Design



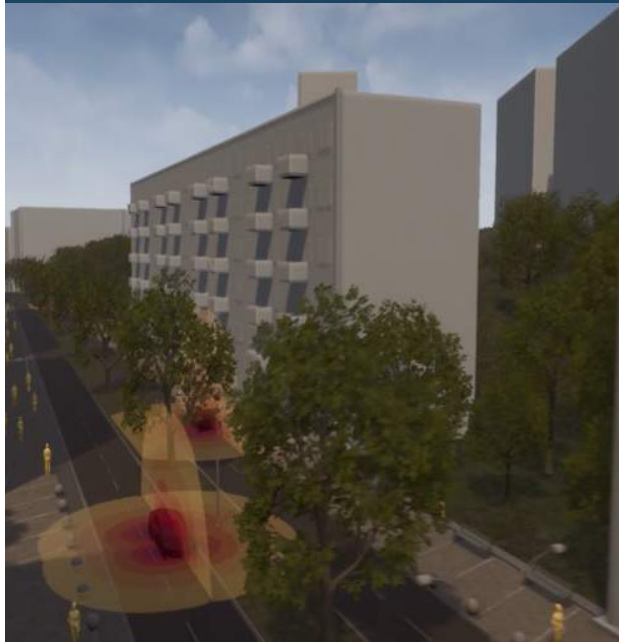
RA3 – Digital Construction



RA4/5 – Modelling & Simulation



RA6 – Visualization & Auralization



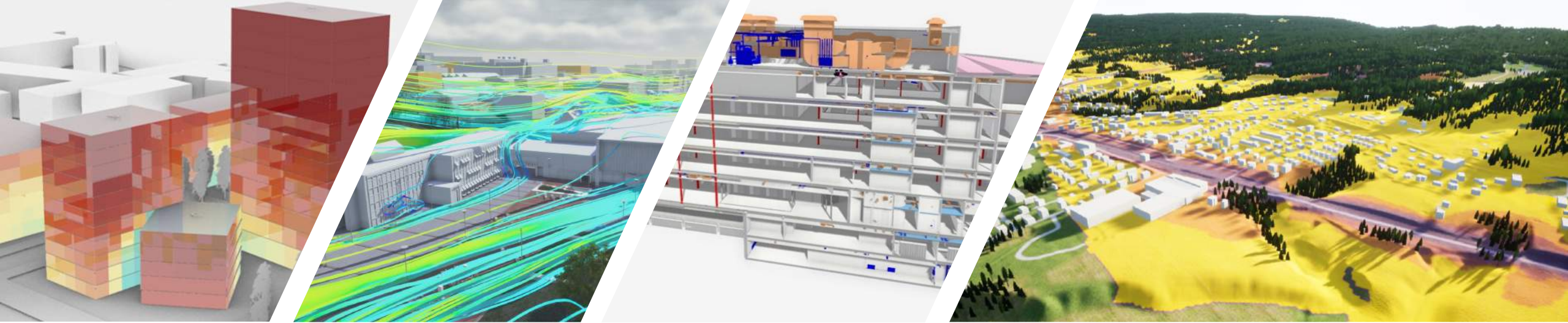
RA7 – Data Management



Innovation & Education

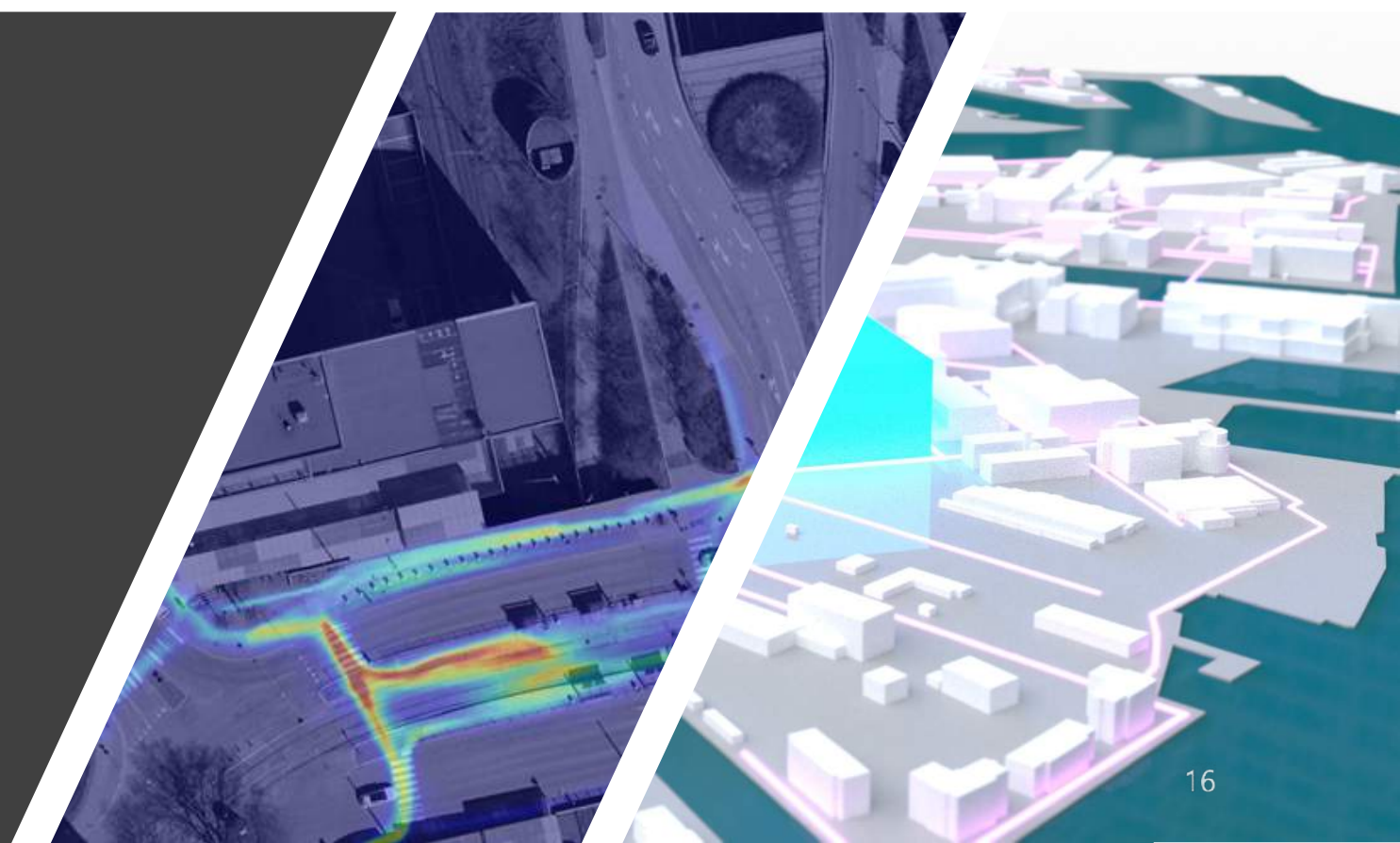


Research areas



Milestone Projects

- Urban Environmental Comfort Design
- Crowd Movement
- Digital Twins for Circularity
- Design & Data
- Twinable
- Data Models for Digital Twins
- Digital Twin of Construction Site



Project Highlights

Visualization of Environmental Data (Miljövis)

Beata Stahre Wästberg, Monica Billger, Liane Thuvander
Vasilis Naserentin, Orfeas Eleftheriou, Fabio Latino
Sanjay Somanath, Susanne van Raalte



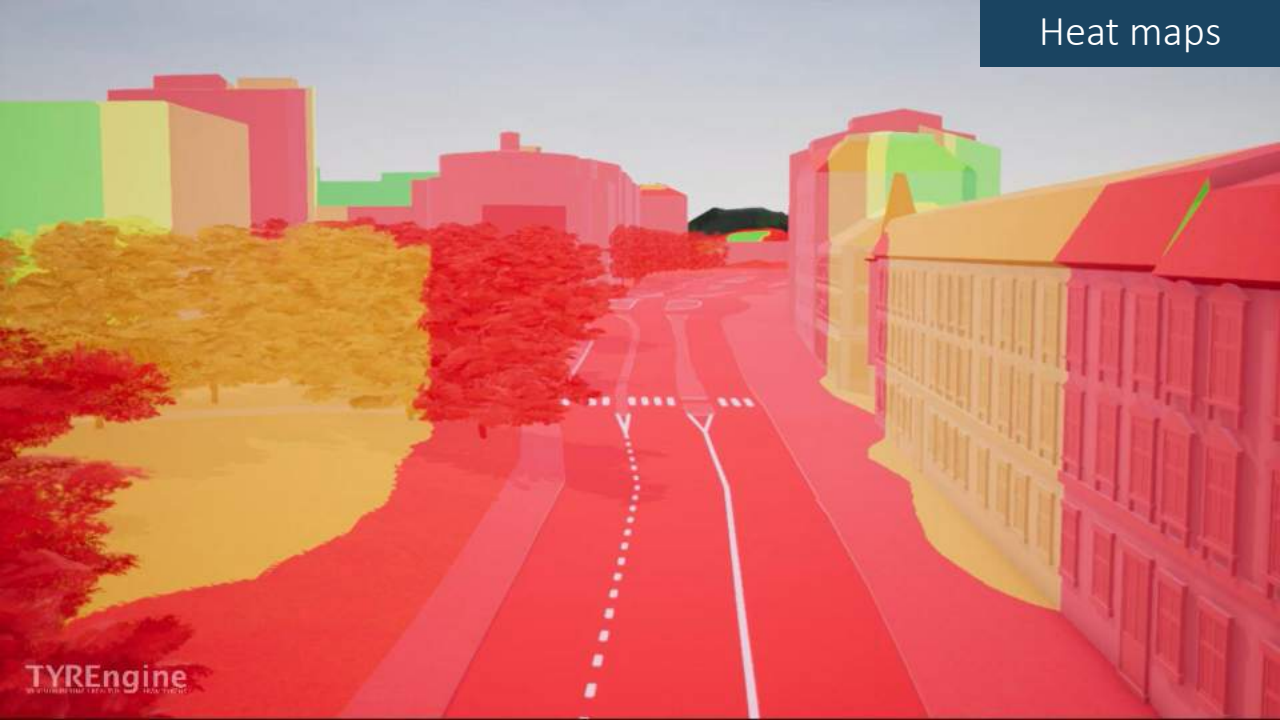
How to visualize the invisible?

- Develop new methods for visualization of environmental data
- Apply and evaluate methods together with Trafikverket

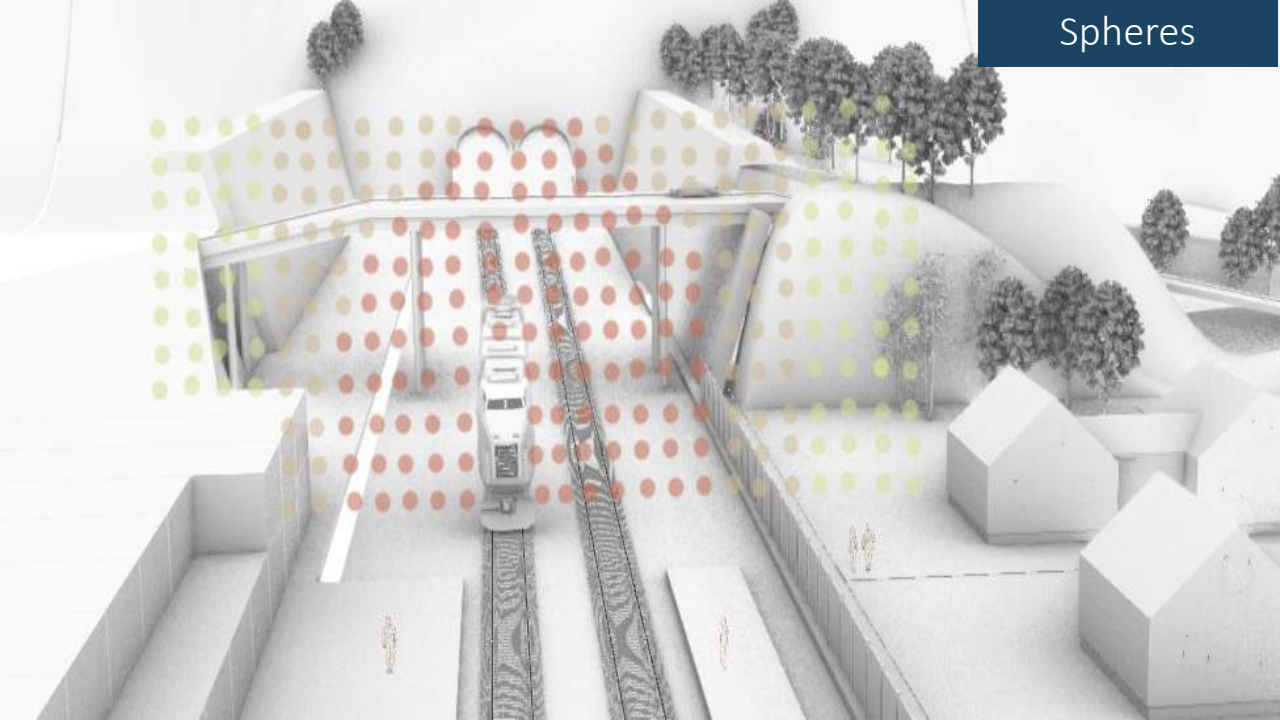




Development of large-scale prototype



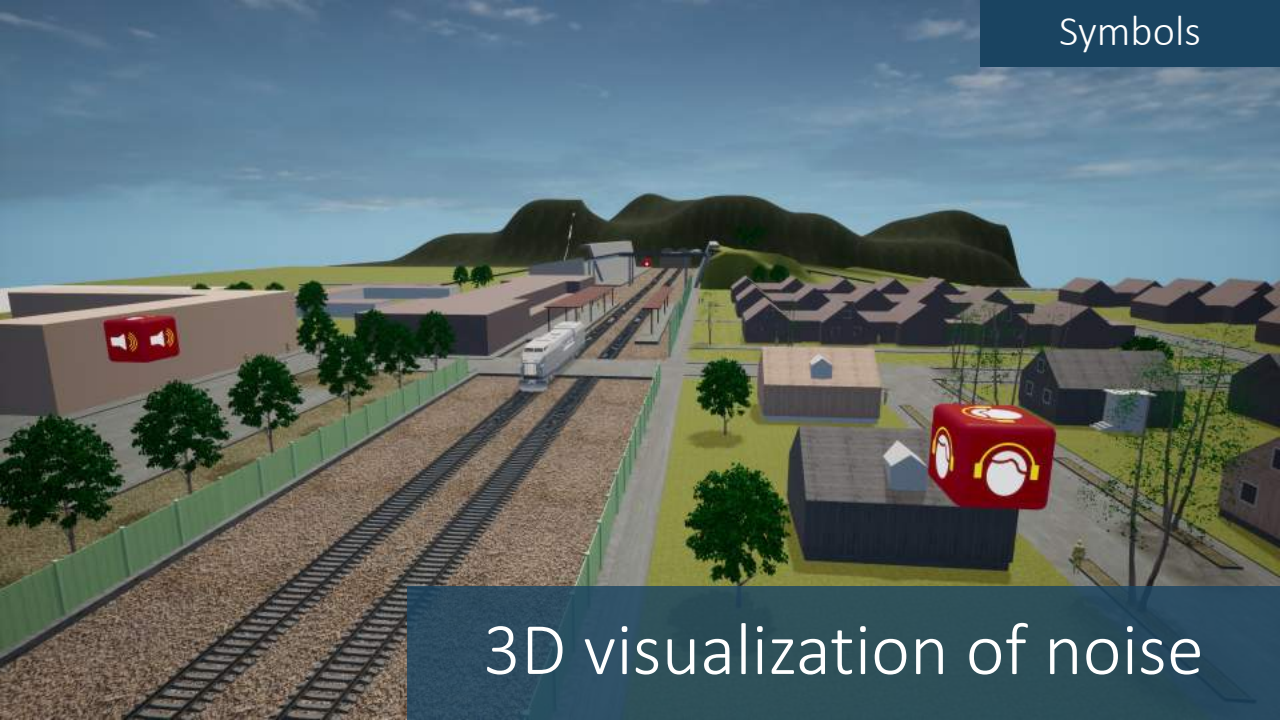
Heat maps



Spheres

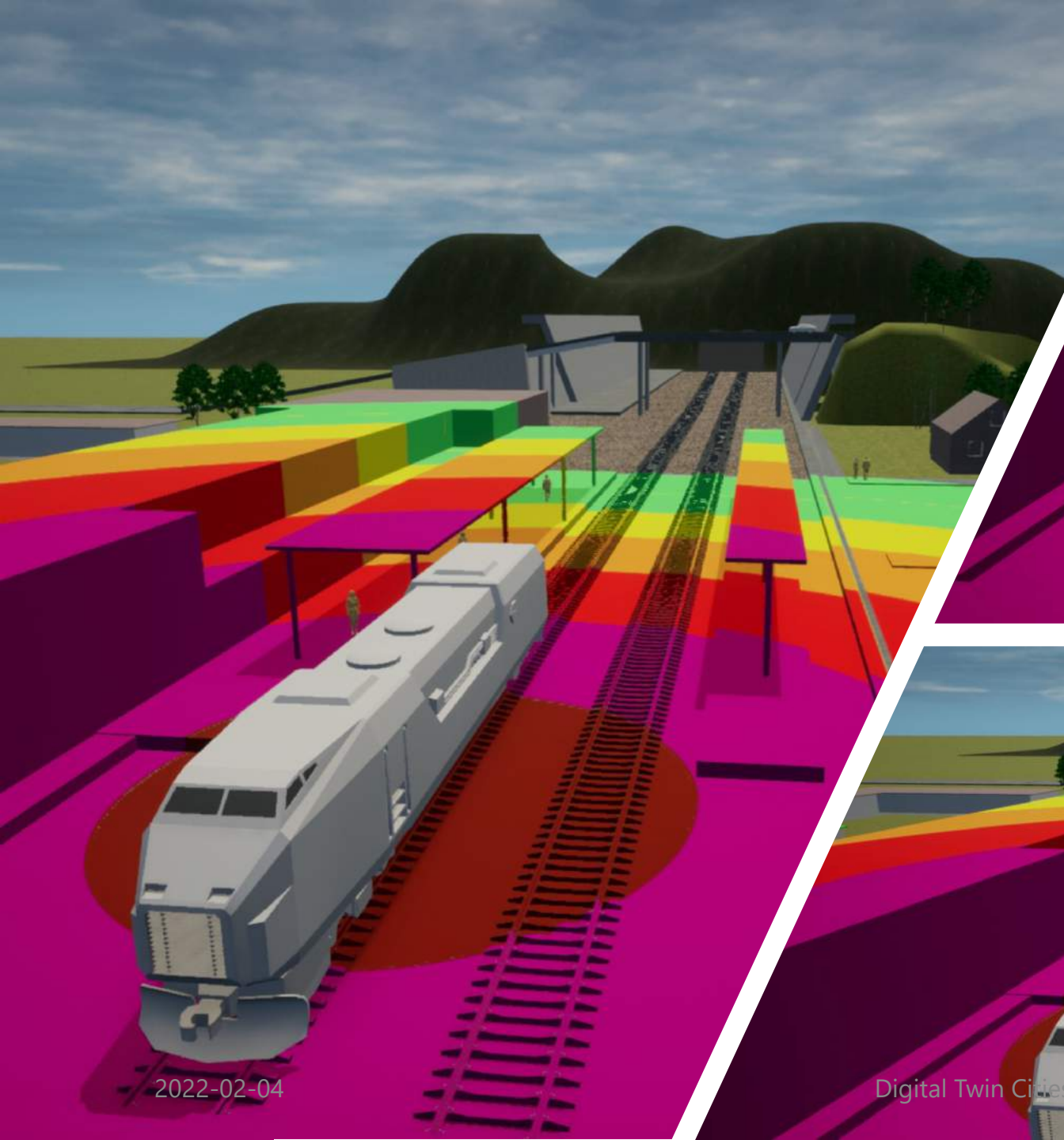


Particles

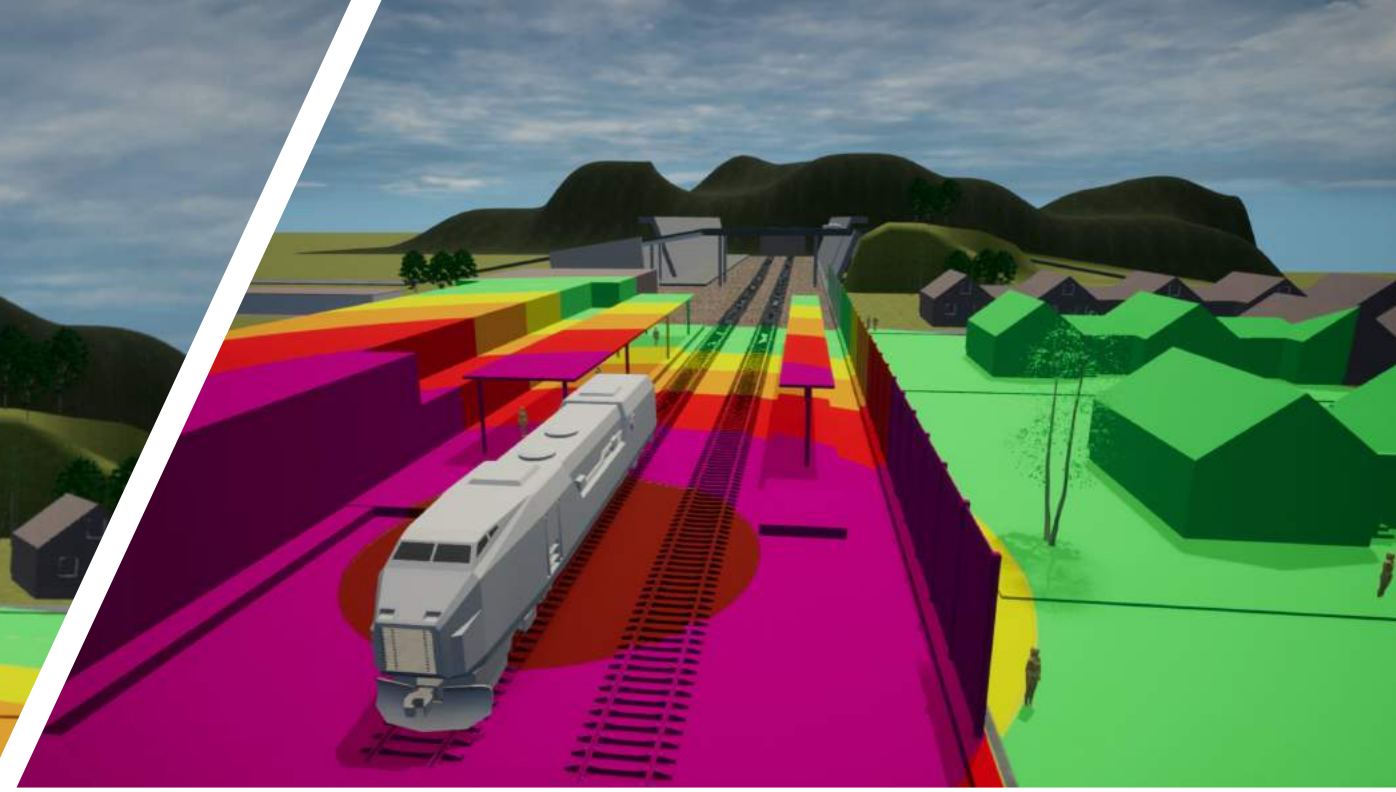


Symbols

3D visualization of noise



2022-02-04



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The effect of noise planks

High-Performance Mesh Generation

Anders Logg, Vasilis Naserentin

Dag Wästberg, Nikolay Kolibarov

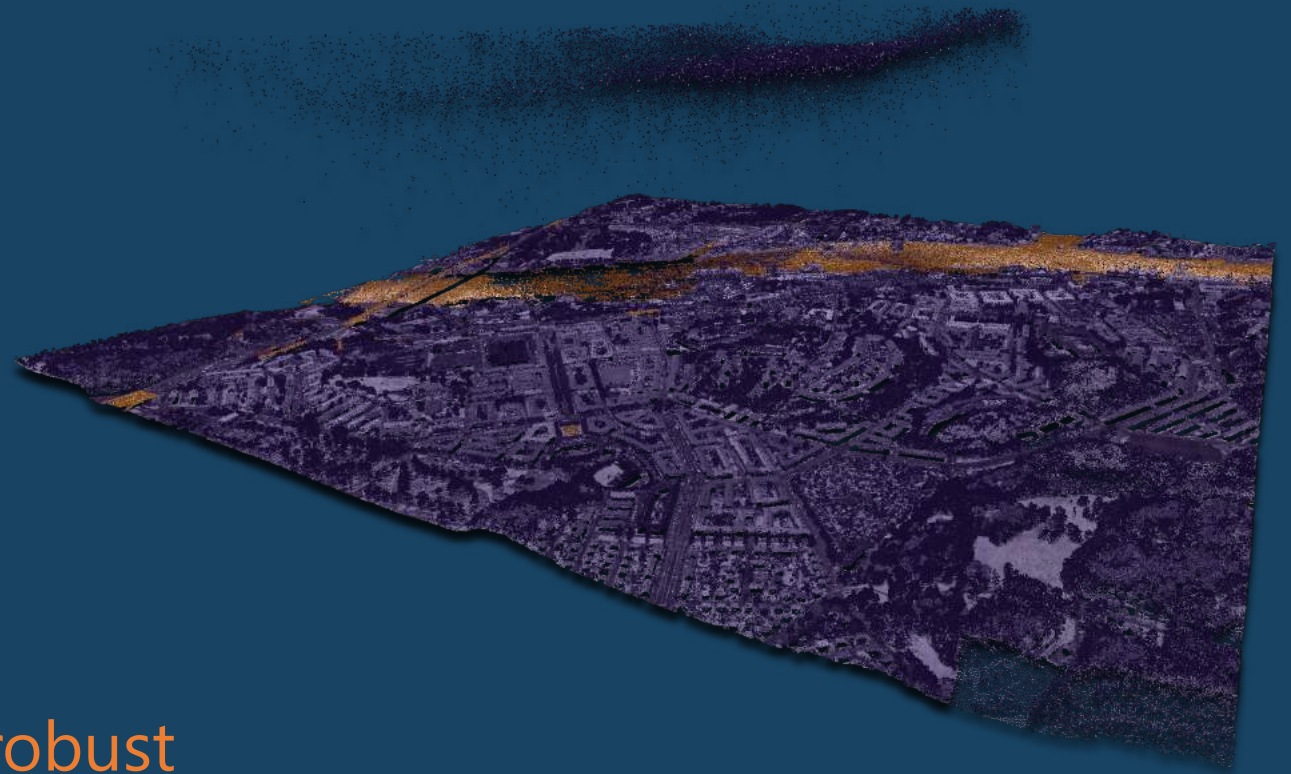


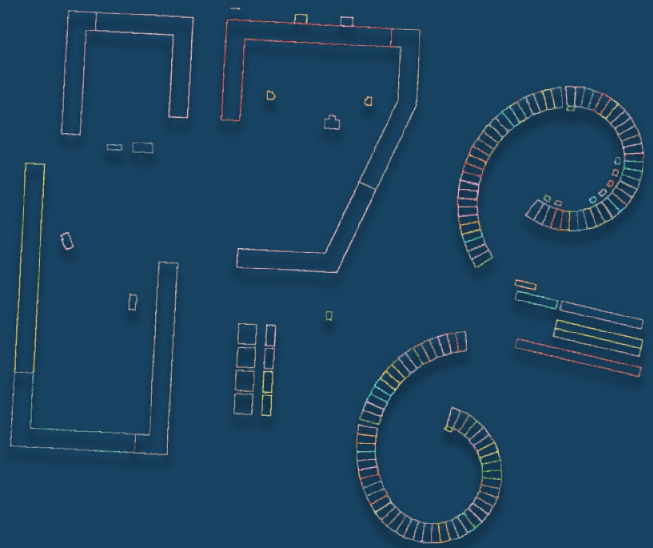
RAMBOLL

GATE

How to generate 3D models from raw data?

- Develop new methods for generation of 3D models for high-performance city simulation
- Use available raw data from Lantmäteriet
- Should be **automatic, efficient, robust**





Step 1
Generate city model

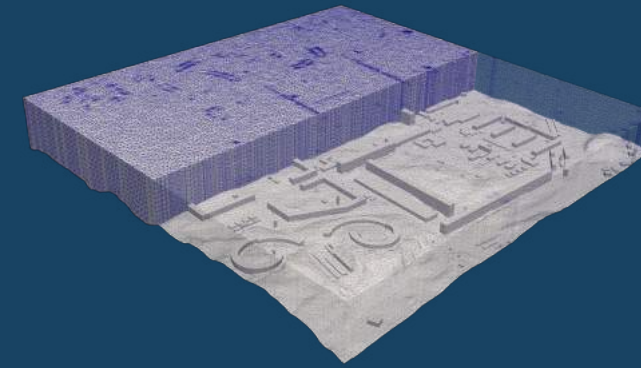
- Step 1.1
Read point cloud data
- Step 1.2
Read building footprints
- Step 1.3
Compute digital terrain map
- Step 1.4
Clean building footprints
- Step 1.5
Extract buildings points
- Step 1.6
Compute building heights
- Step 1.7
Export city model

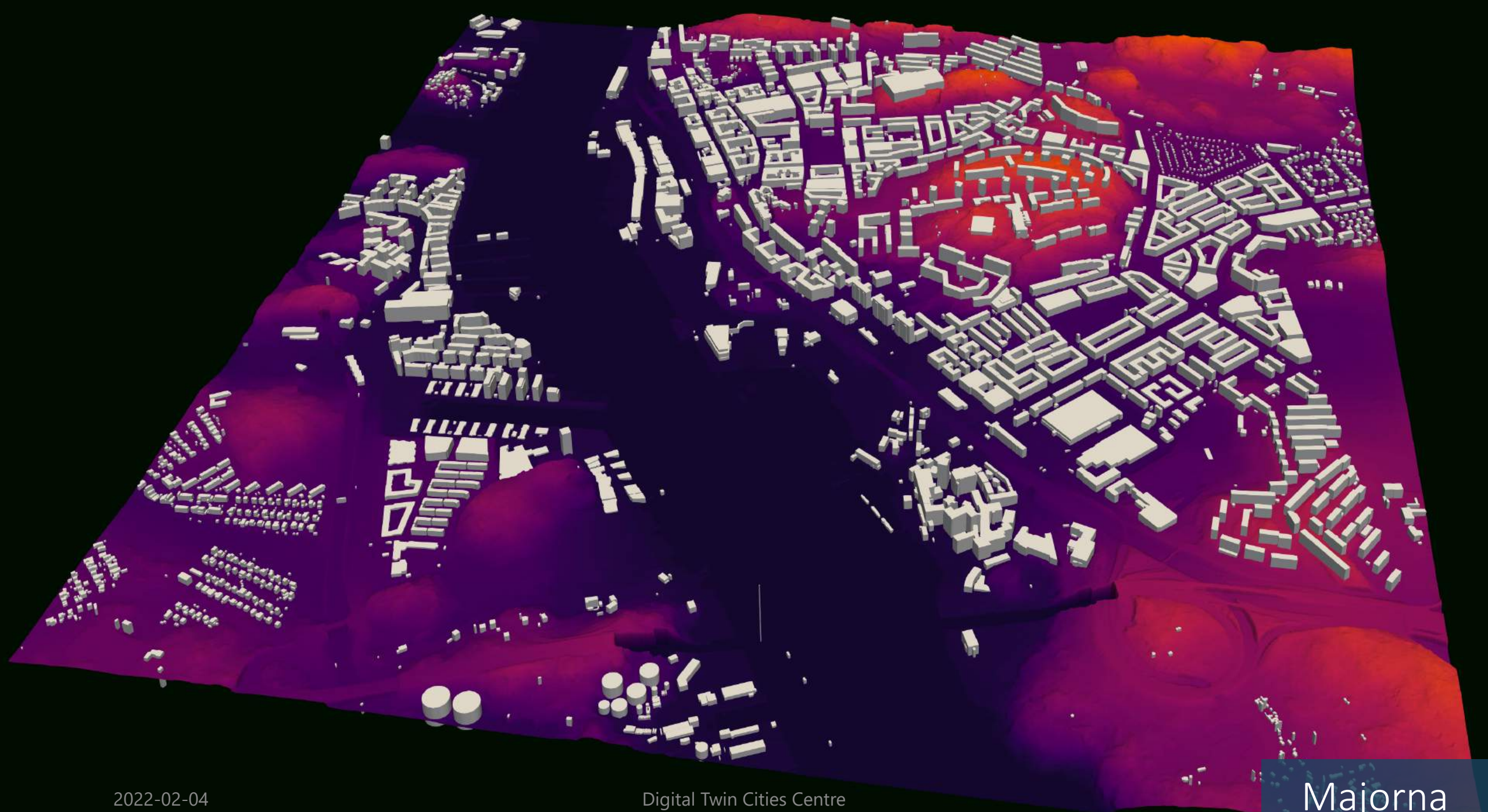
Step 2
Simplify city model

- Step 2.1
Merge building footprints
- Step 2.2
Clean building footprints
- Step 2.3
Compute building heights
- Step 2.4
Export simplified city model

Step 3
Generate city mesh

- Step 3.1
Generate 2D mesh
- Step 3.2
Generate 3D mesh
- Step 3.3
Smooth 3D mesh
- Step 3.4
Trim 3D mesh
- Step 3.5
Smooth 3D mesh
- Step 1.6
Export mesh

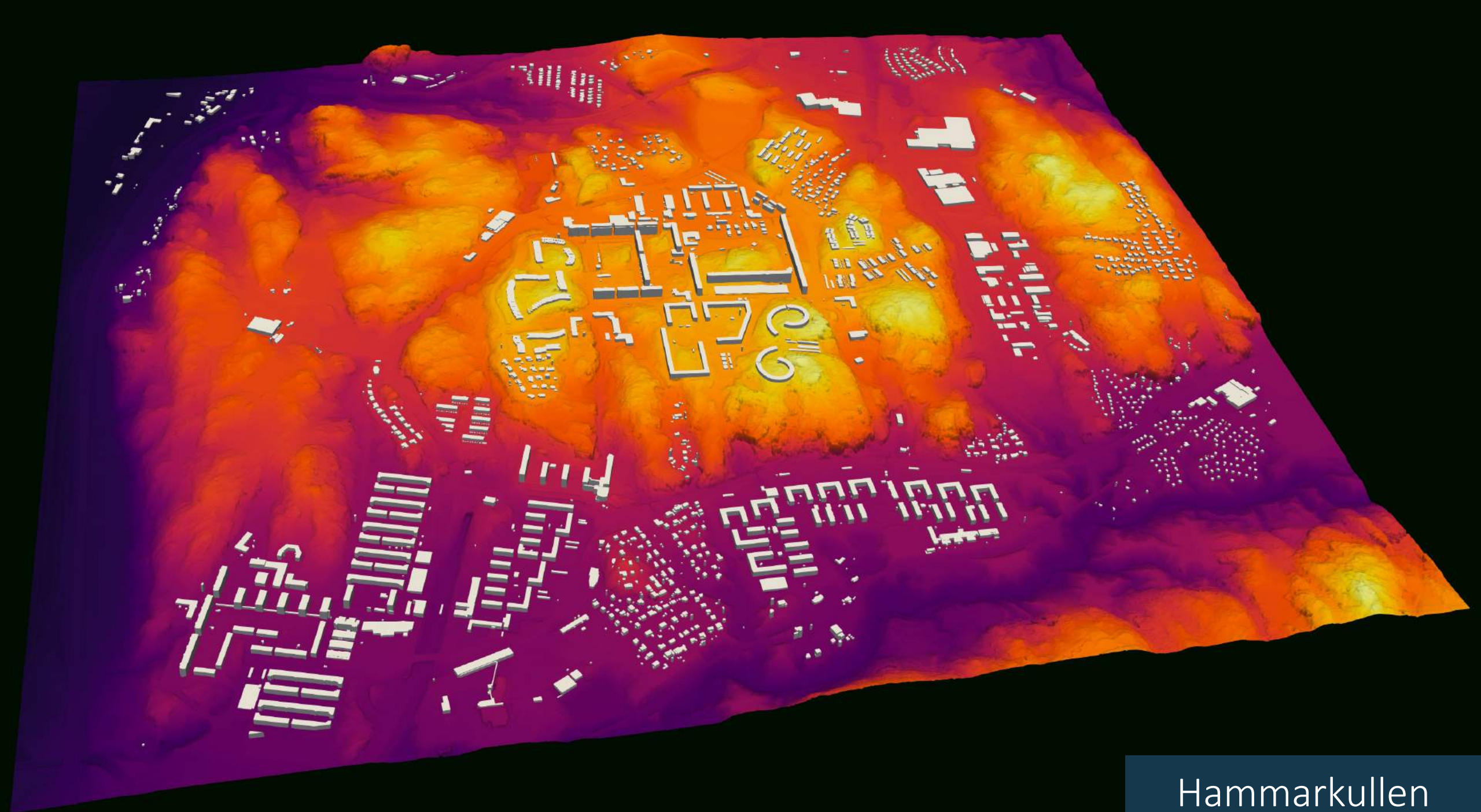




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Majorna



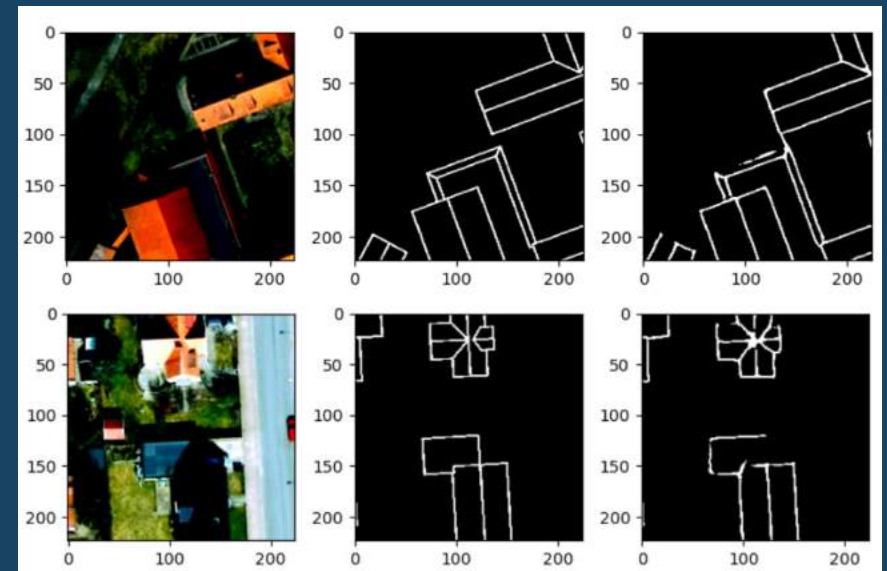
Hammarkullen

Ongoing work

- From LOD1 to LOD2
- Automatic roof segmentation
- Point cloud + orthophotos
- Supervised learning of DNN



[Biljecki]



High-Performance City Simulation

Andreas Mark, Franziska Hunger, Fredrik Edelvik

Dag Wästberg, Radostin Mitkov

Vasilis Naserentin, Anders Logg



FRAUNHOFER CHALMERS
RESEARCH CENTRE FOR INDUSTRIAL MATHEMATICS

RAMBOLL

GATE



How should **automated workflows** be designed to support urban planners and architects to assess **urban wind comfort**?

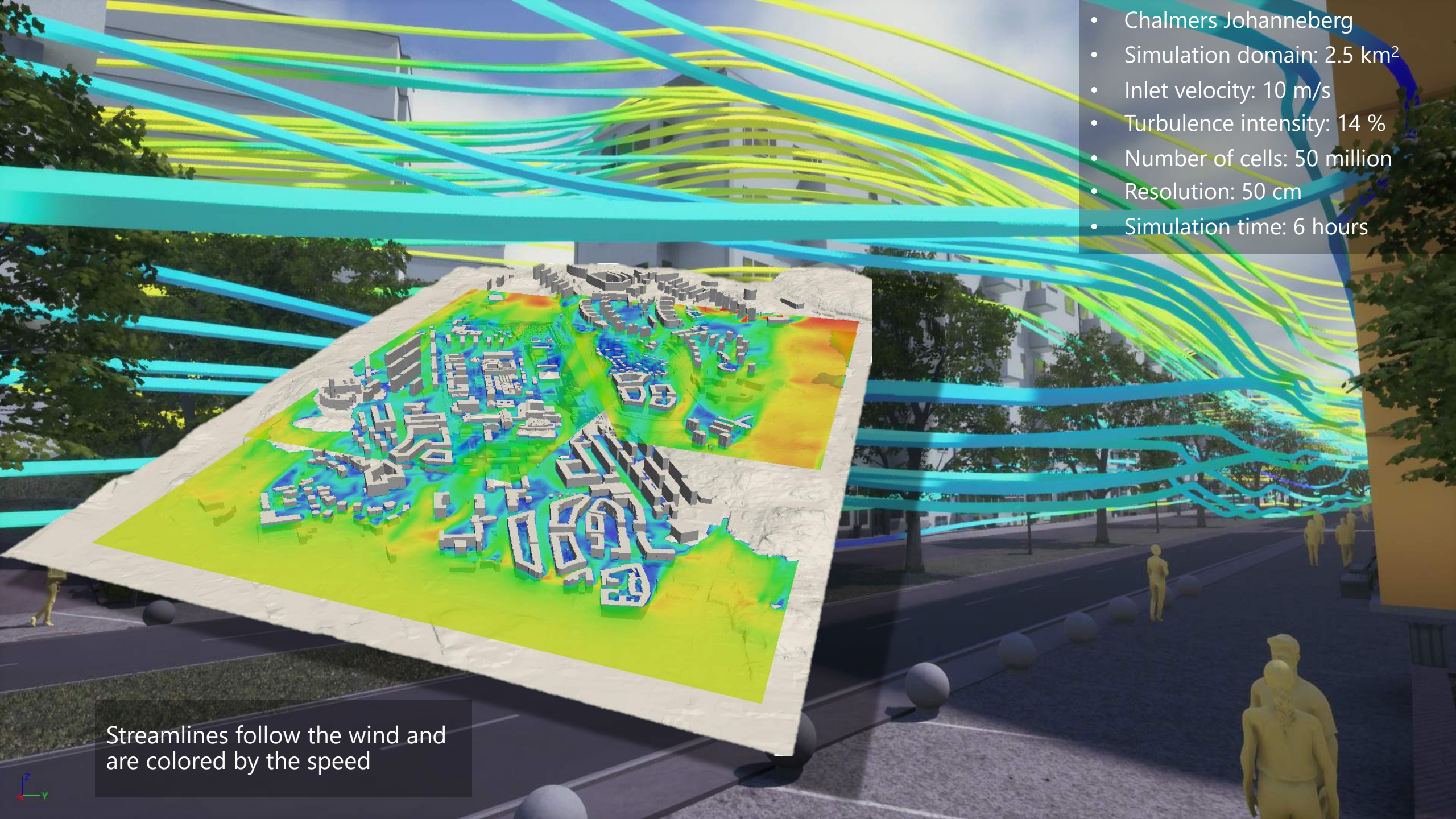
- **Integrate** geometry extraction, meshing, high-performance simulation and high-end visualization in the **Digital Twin Platform**
- Quantify and visualize results



- Chalmers Lindholmen
- Simulation domain: 1.6 km²
- Inlet velocity: 10 m/s
- Turbulence intensity: 1 %
- Number of cells: 50 million
- Resolution: 25 cm
- Simulation time: 12 hours

The visualization plane shows the wind speed at ground level

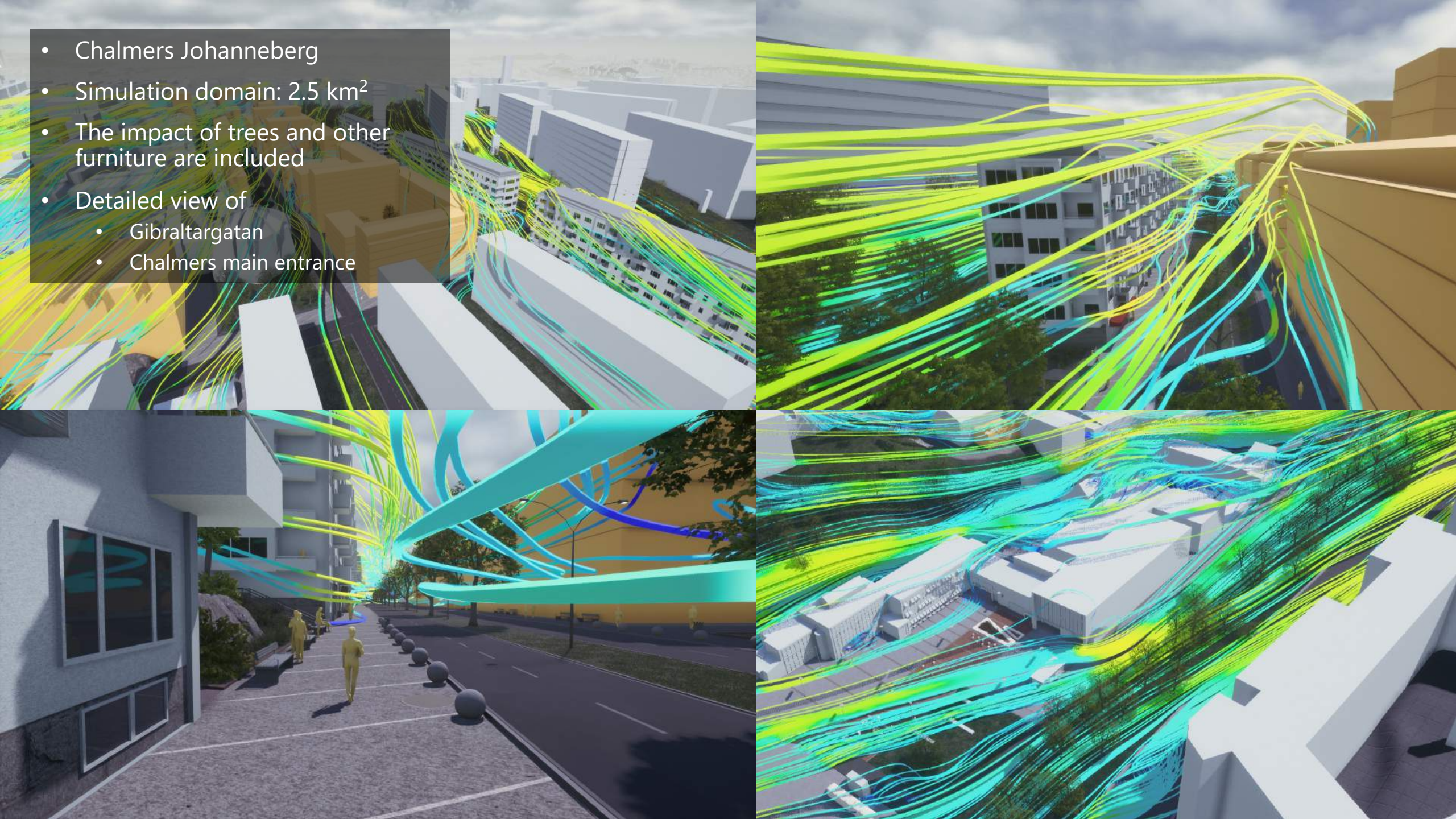
- Chalmers Johanneberg
- Simulation domain: 2.5 km²
- Inlet velocity: 10 m/s
- Turbulence intensity: 14 %
- Number of cells: 50 million
- Resolution: 50 cm
- Simulation time: 6 hours



Streamlines follow the wind and are colored by the speed



- Chalmers Johanneberg
- Simulation domain: 2.5 km²
- The impact of trees and other furniture are included
- Detailed view of
 - Gibraltargatan
 - Chalmers main entrance





dtcc.chalmers.se