

TrackML Challenge Grand Finale Workshop  
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# Hardware-efficient meshes in Computational Fluid Dynamics

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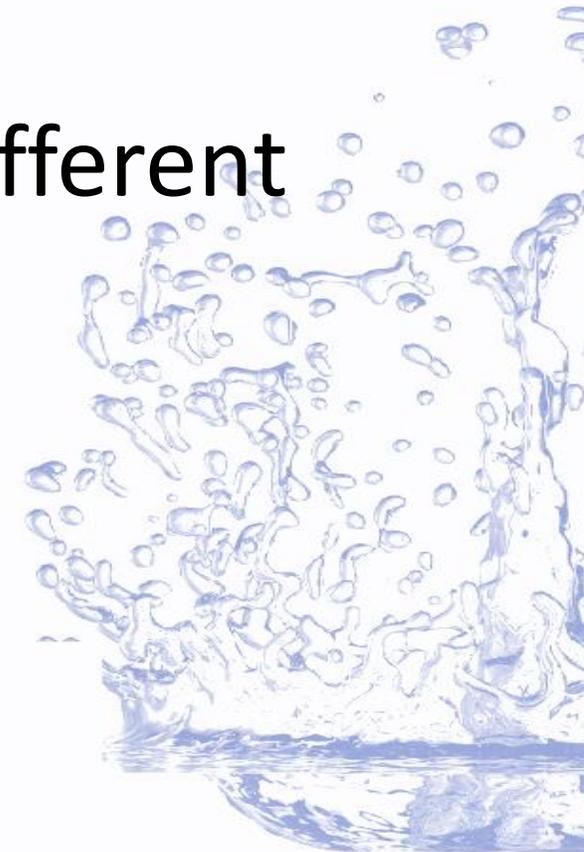
*Centre Universitaire Informatique*

*Université de Genève, Suisse*

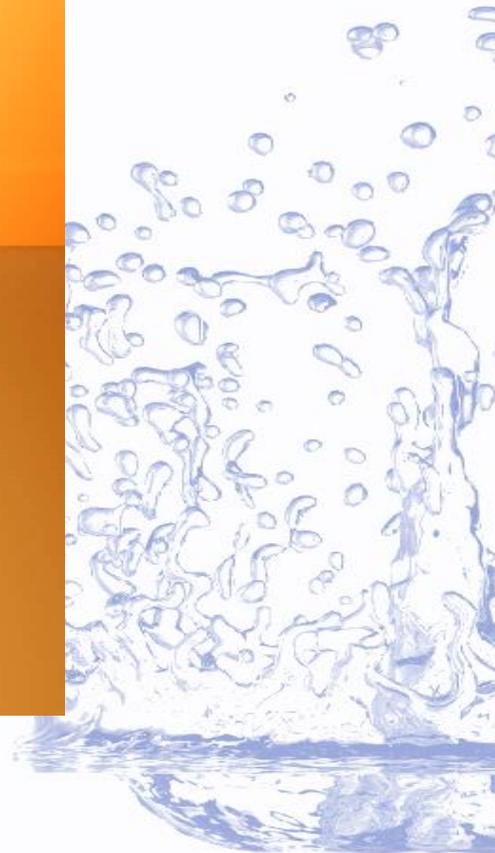
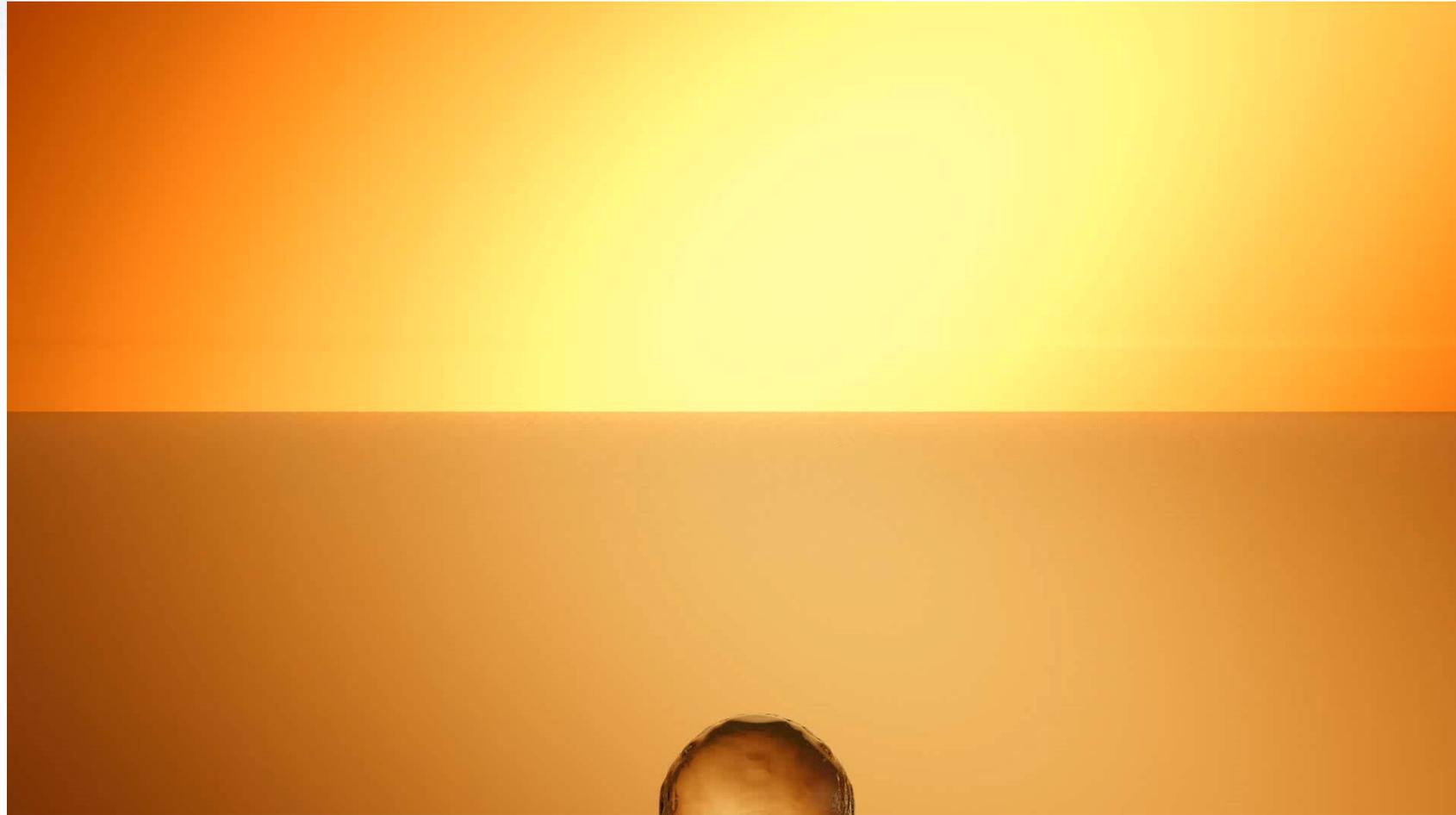


# What's Computational Fluid Dynamics?

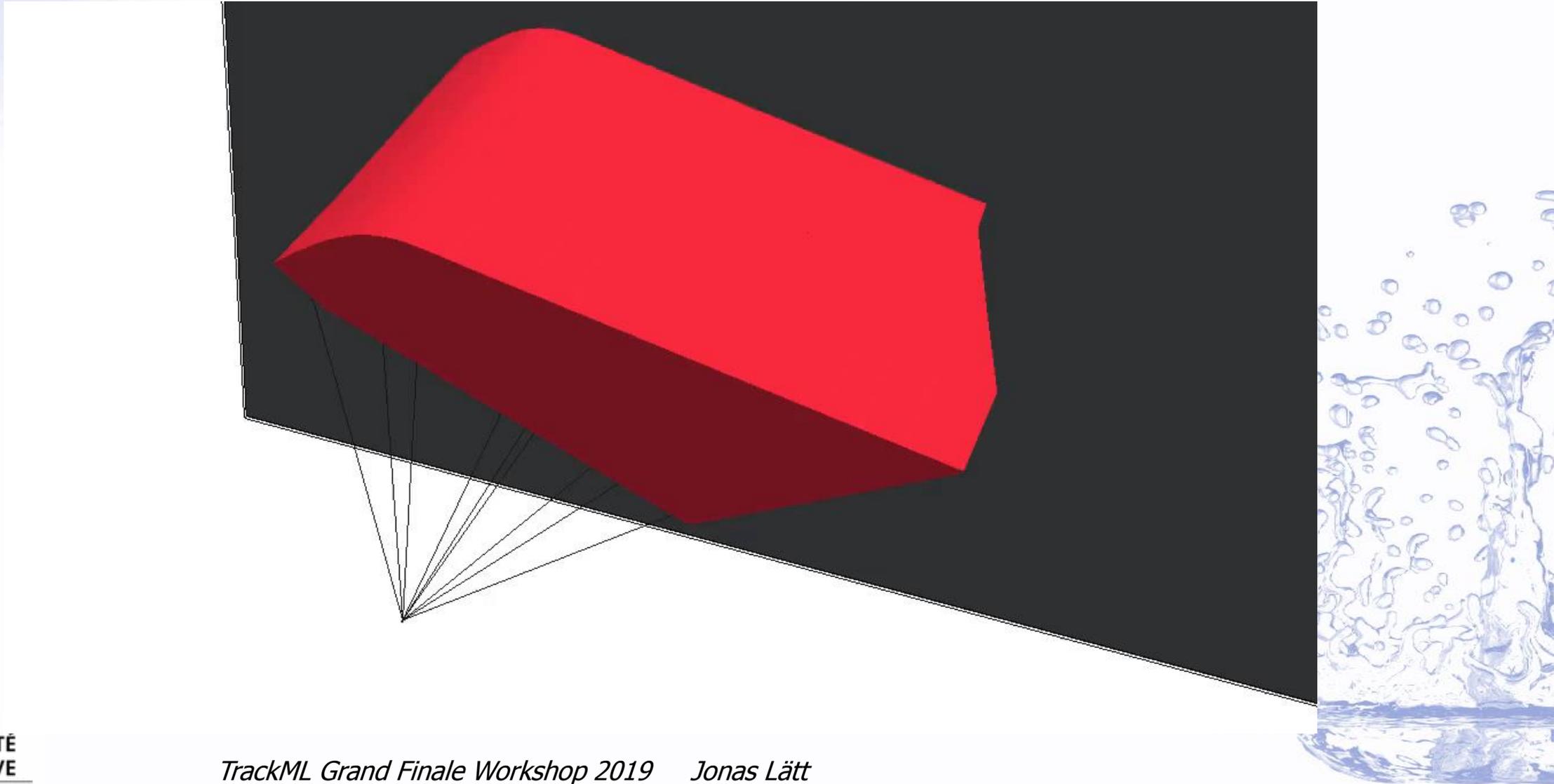
- Simulation of a liquid or gas
- Same numerical model applied to different types of problems



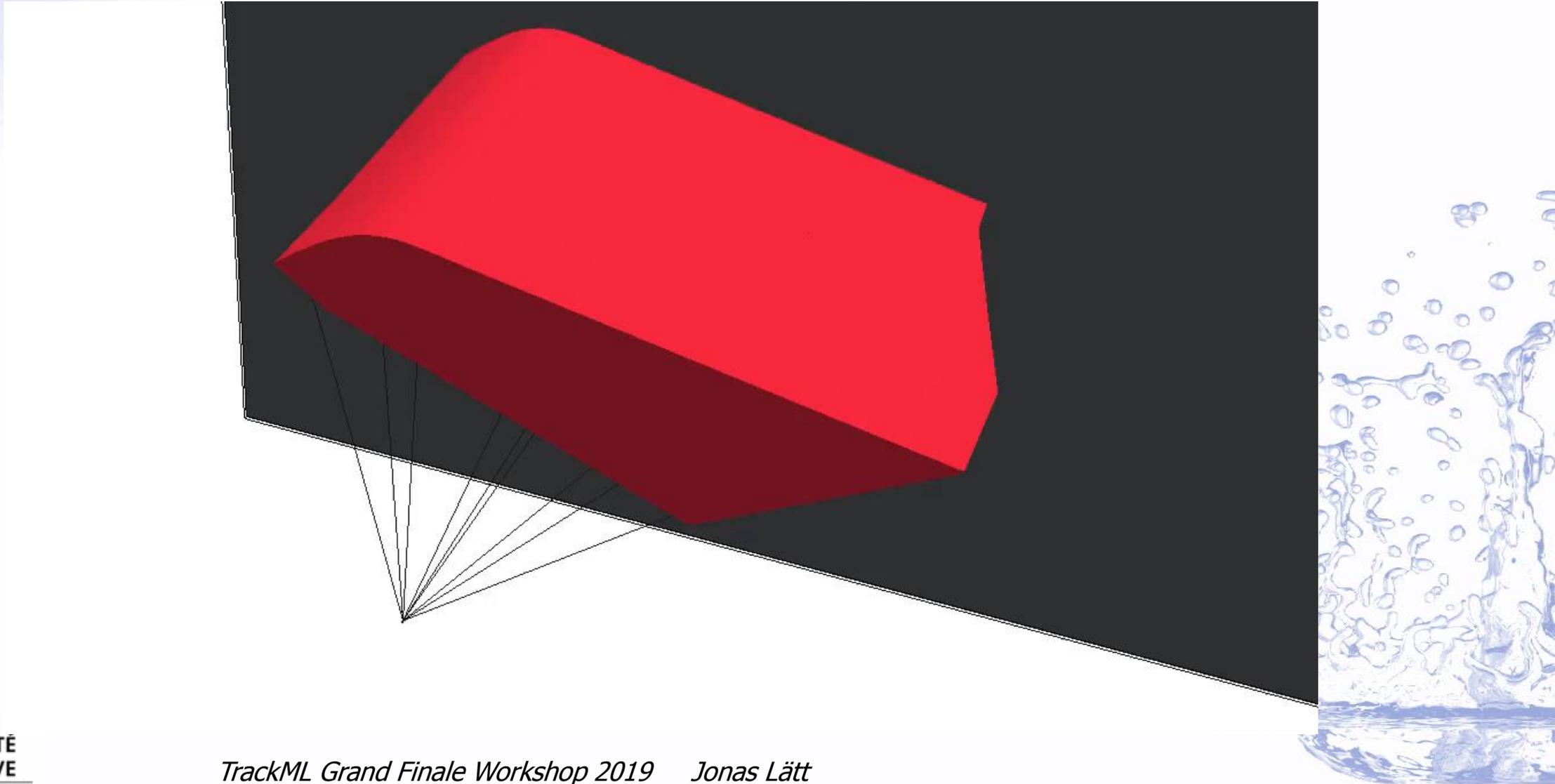
# Example: simulation of water



# Example: kite surfing

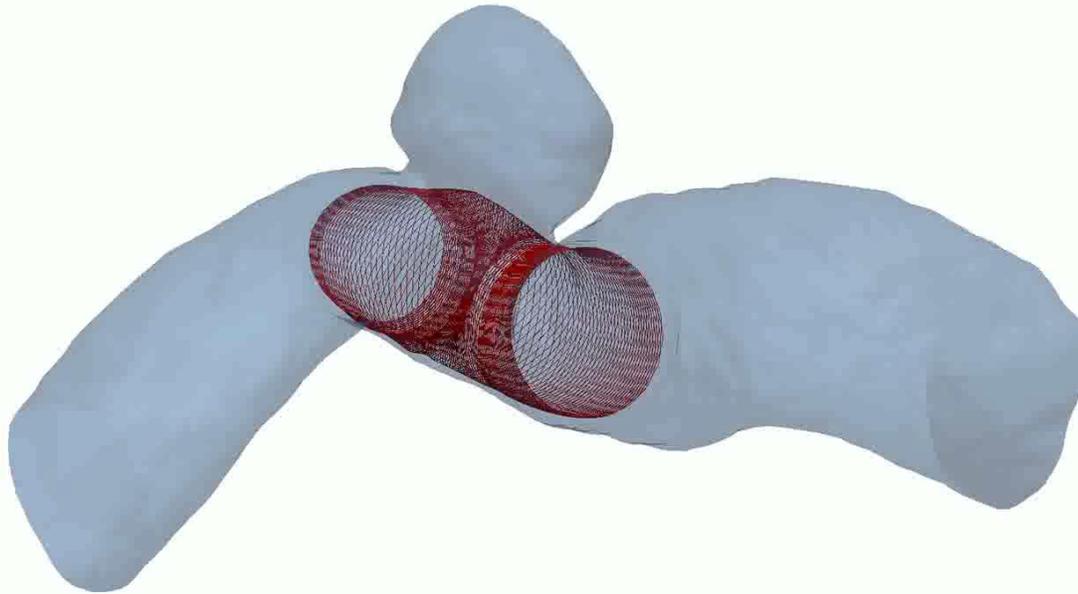


# Example: kite surfing



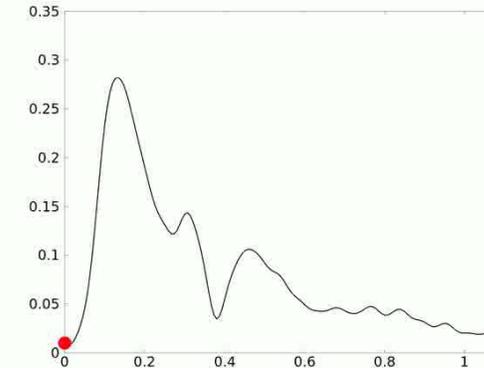
# Example: Blood Flow

Pulsed blood flow in an artery with an aneurysm with stent

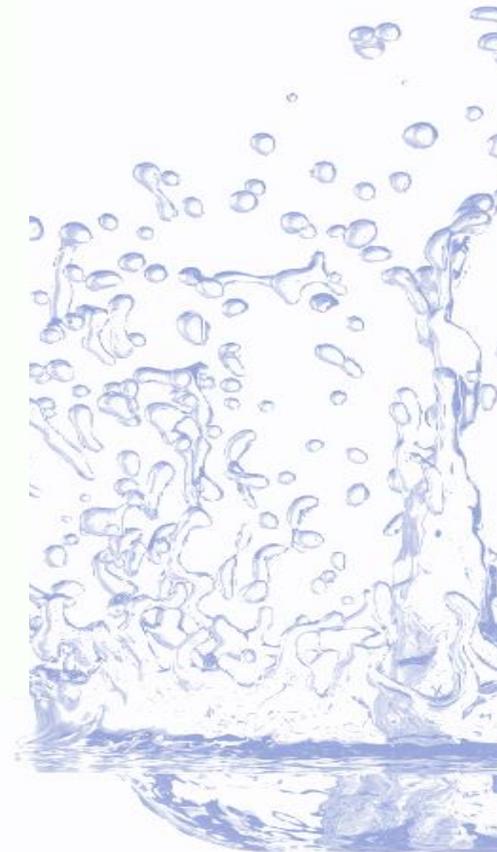
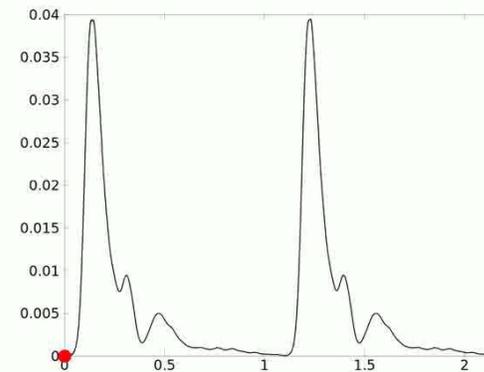


➔ [palabos.org](http://palabos.org)

Average inlet velocity ( $m/s$ ) over time ( $s$ ) ("inlet boundary condition")



Average energy ( $m^2/s^2$ ) over time ( $s$ )

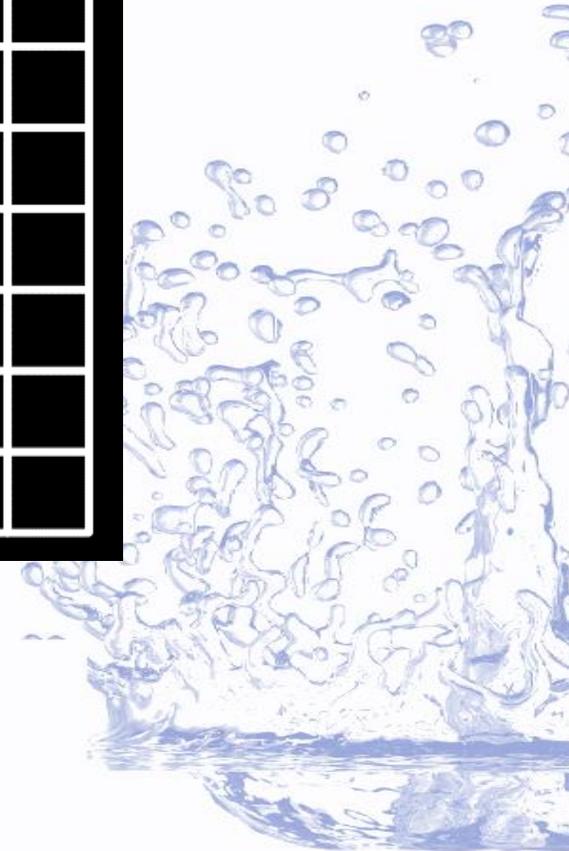
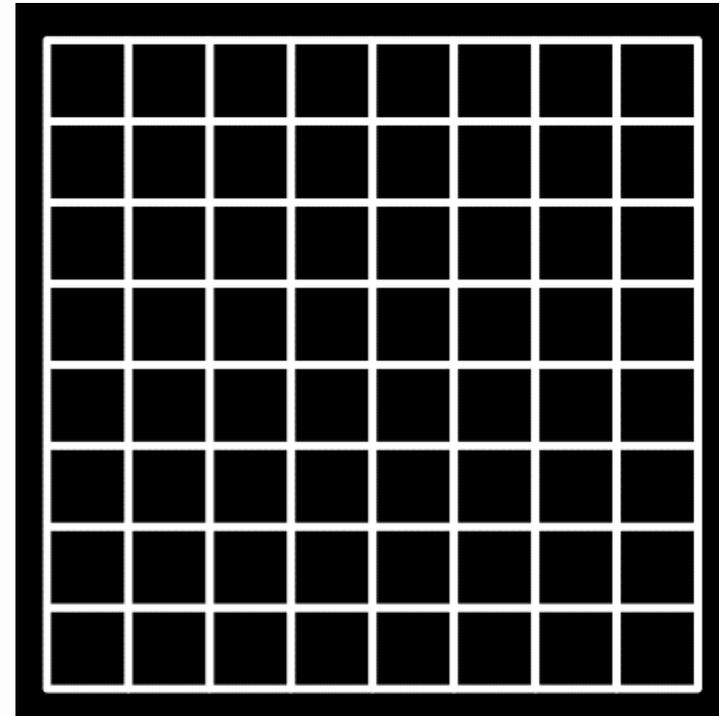
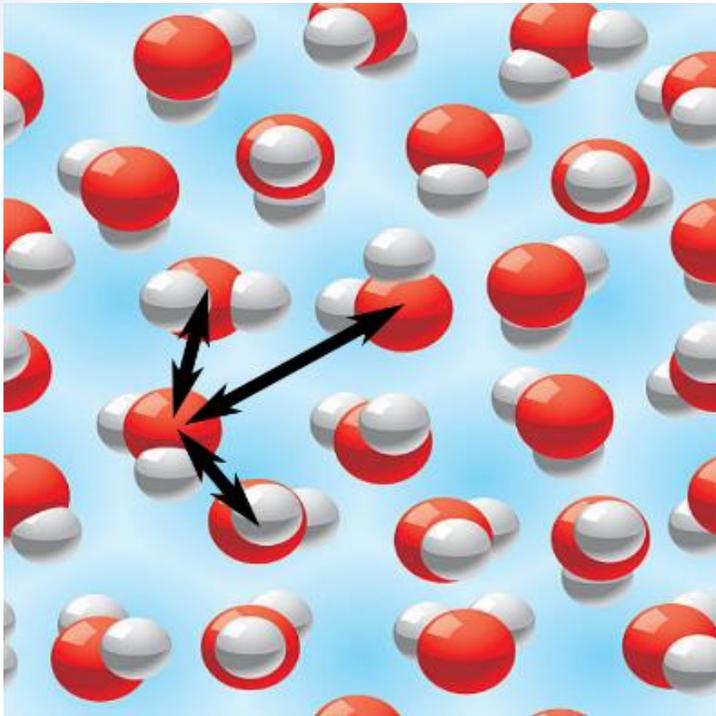


# Challenges of computer simulation

1. Numerical model must be close to reality.
2. Efficient use of computer hardware to obtain results in a reasonable time.

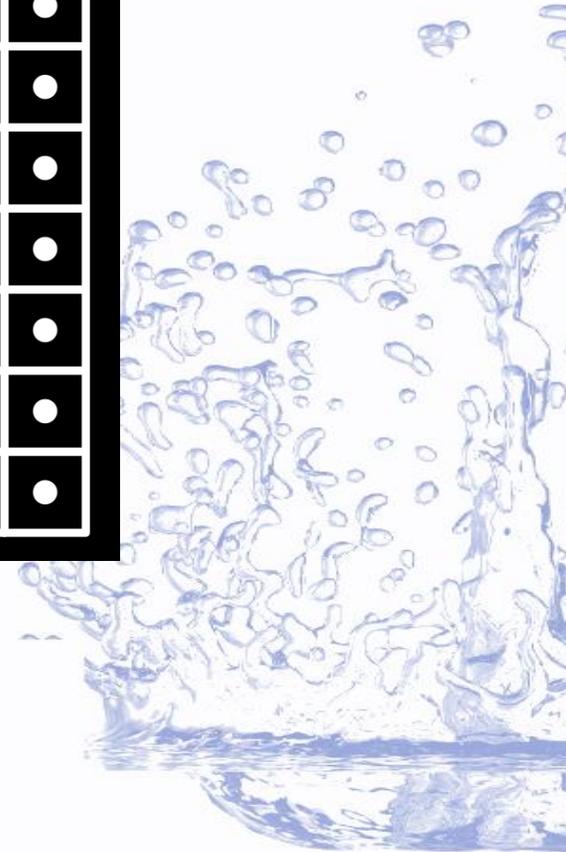
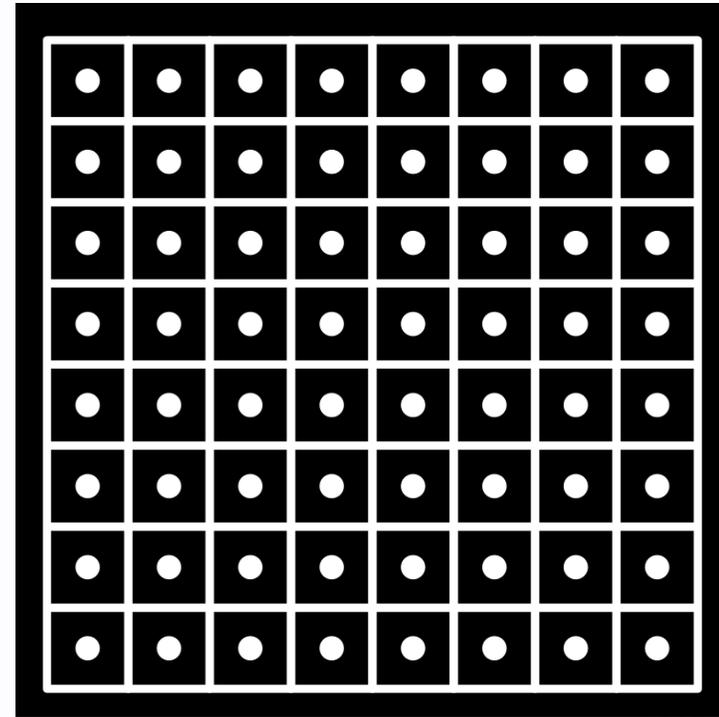
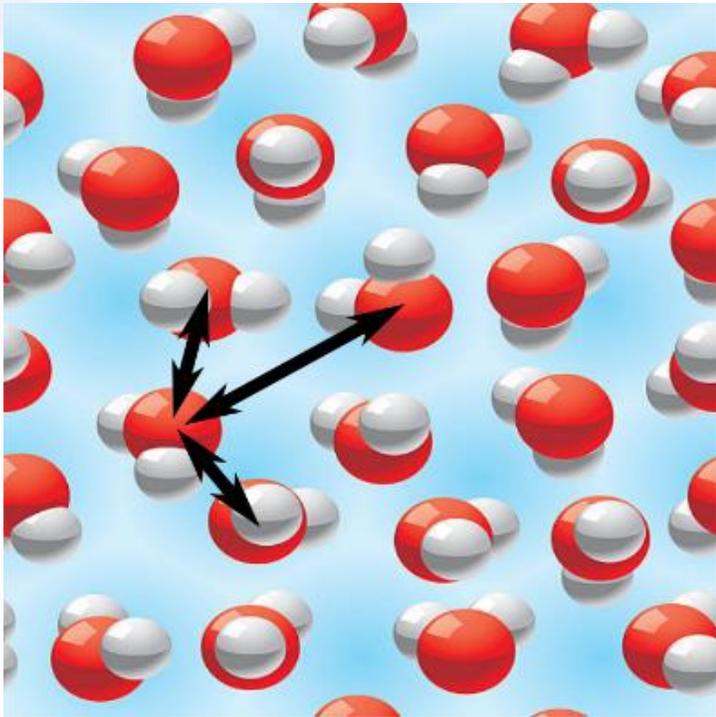


# Model: lattice Boltzmann approach

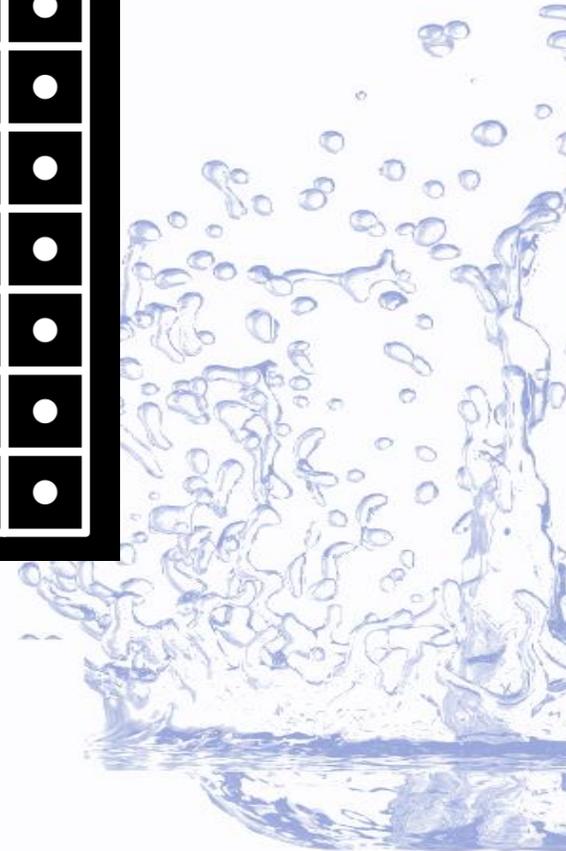
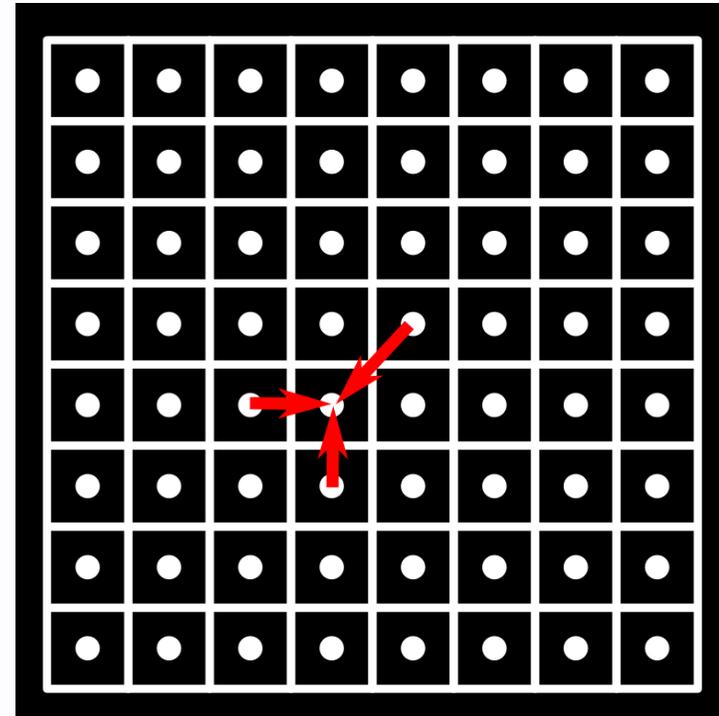
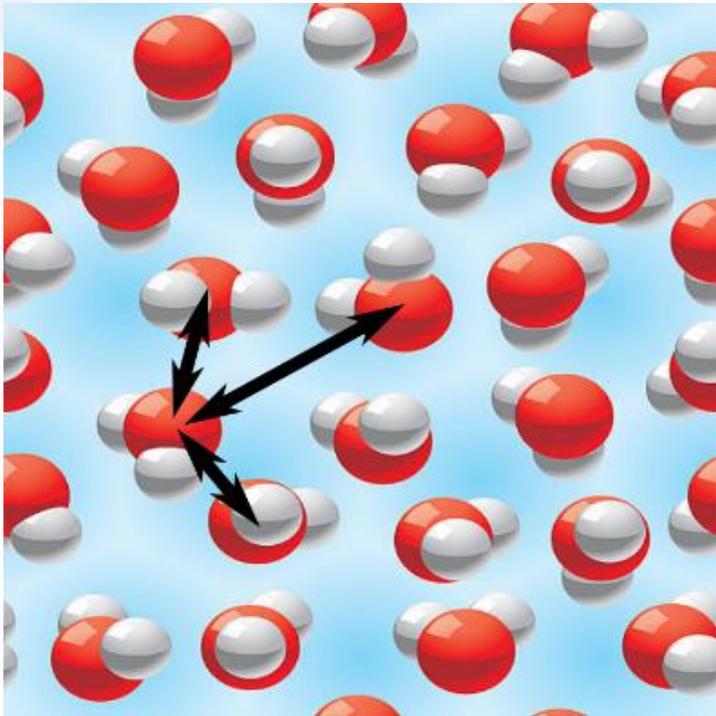




# Model: lattice Boltzmann approach



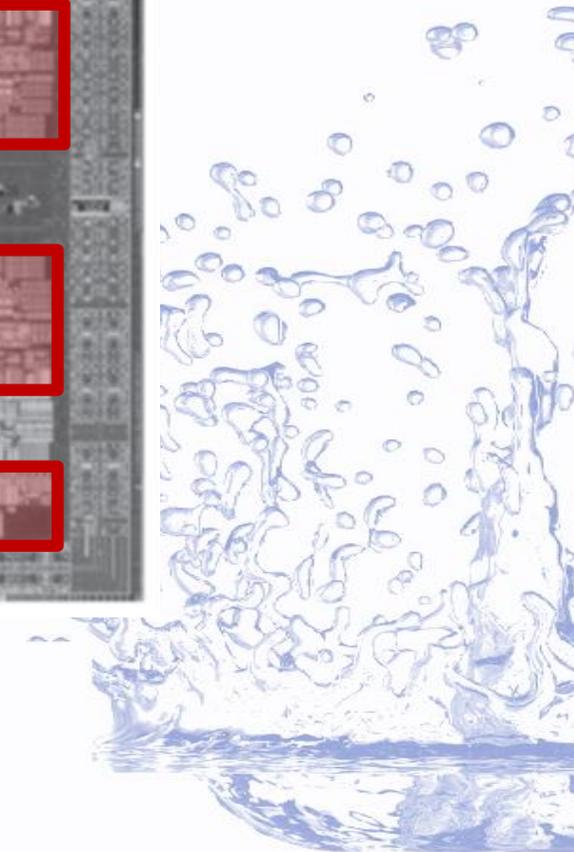
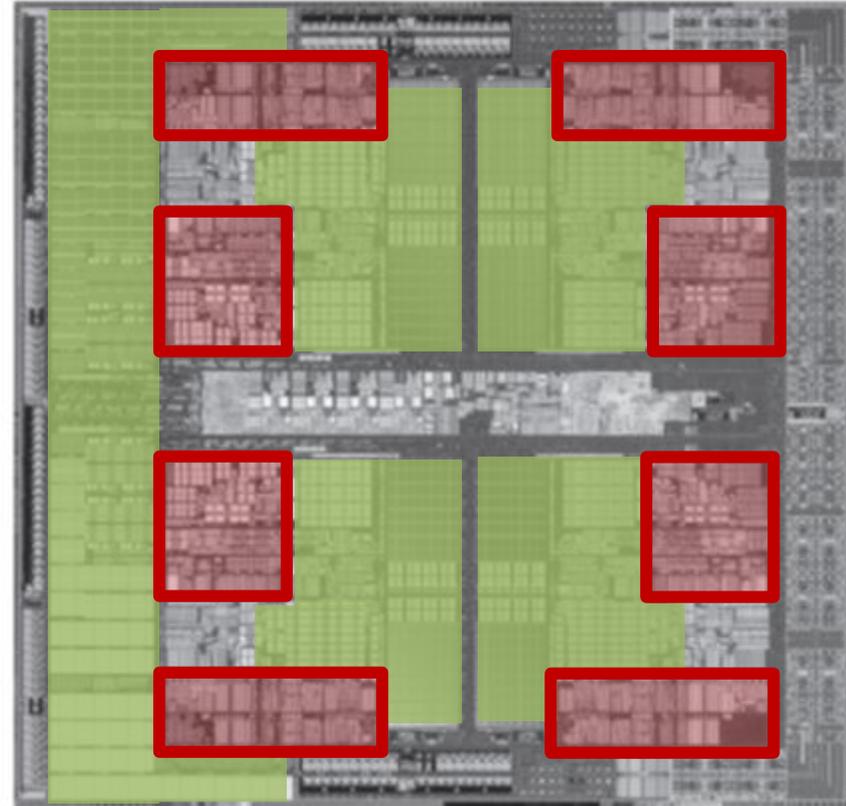
# Model: lattice Boltzmann approach



# Processor architecture

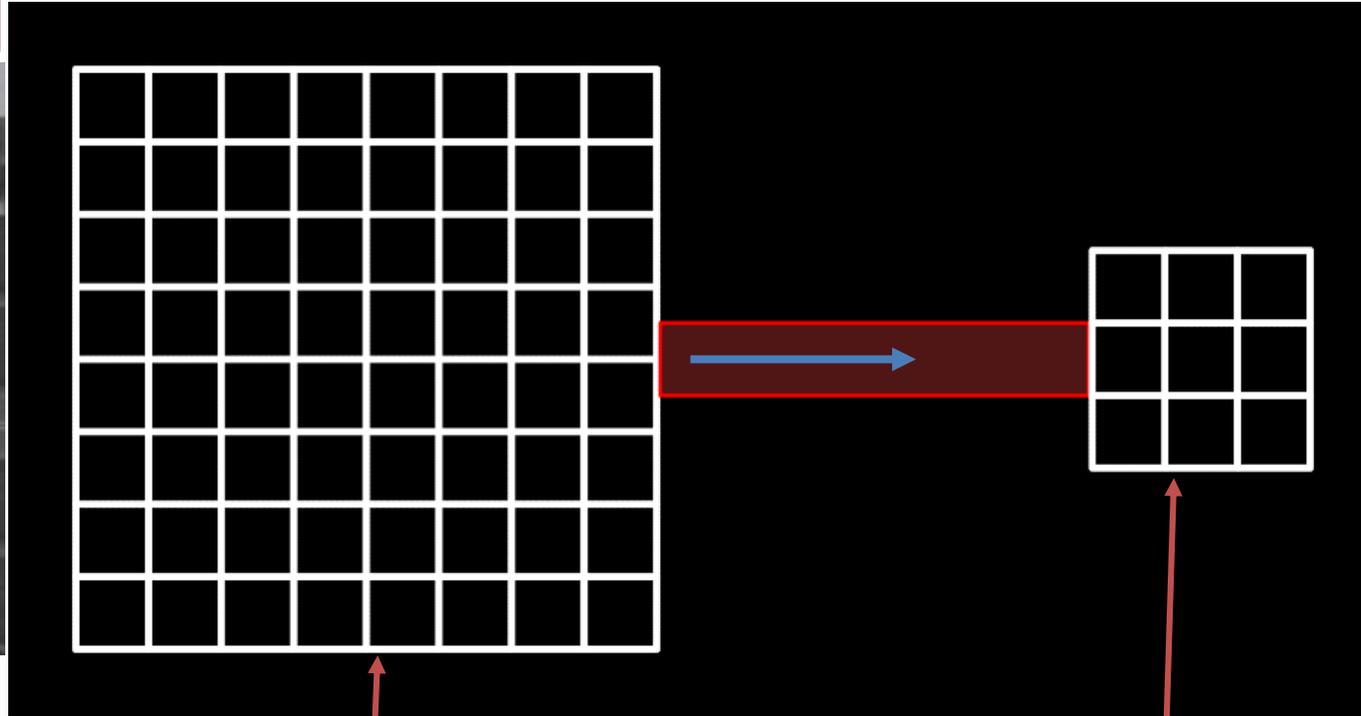
Computations

Cache memory

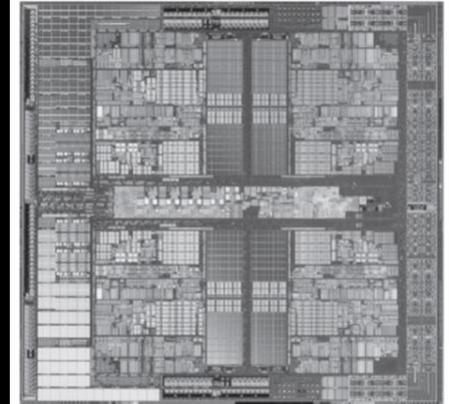


# Cache memory

Central memory



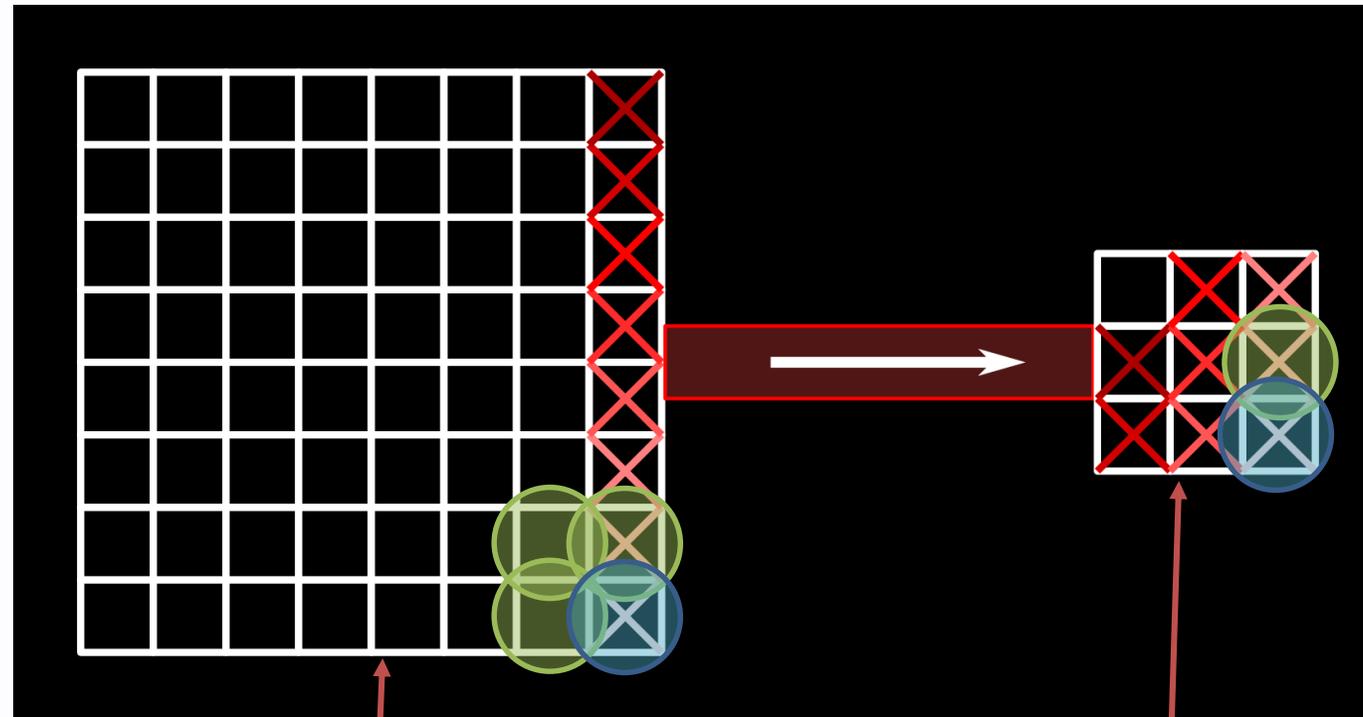
Processor



Simulation data

Data copy in cache memory

# In which order should data be transferred?



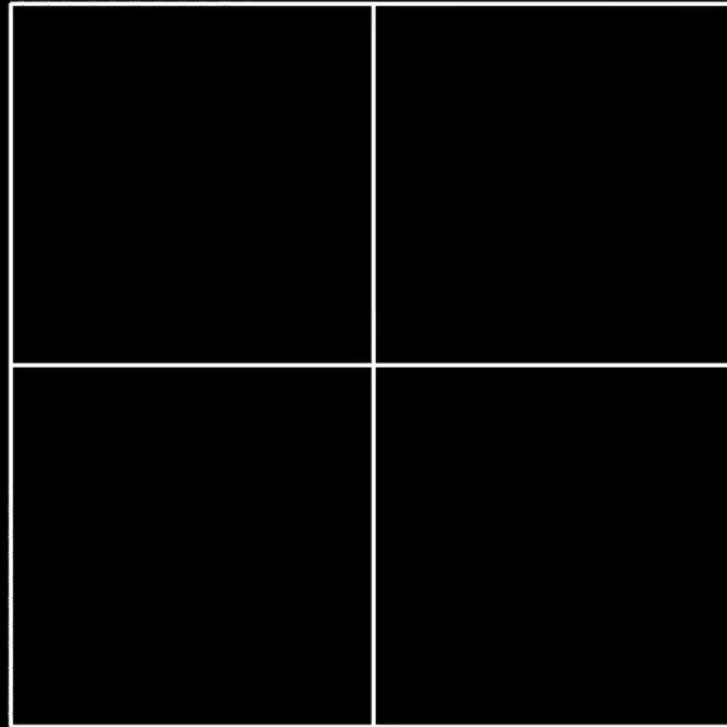
Simulation  
data

Data copy in  
cache memory



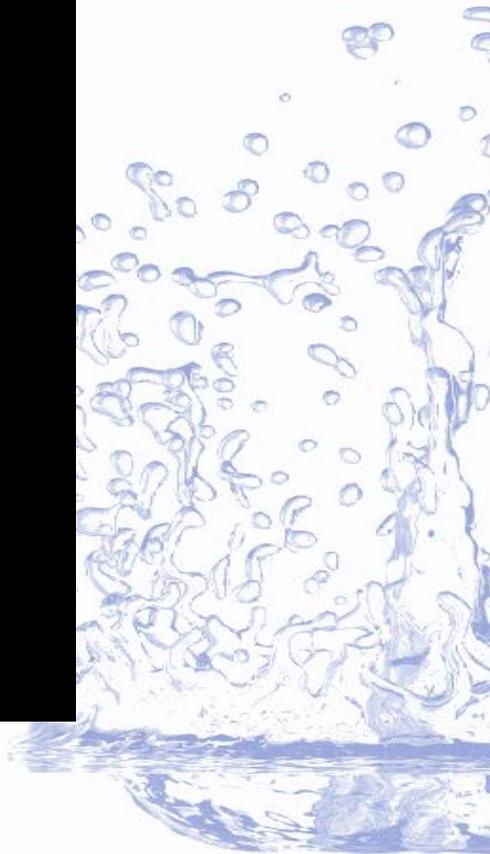
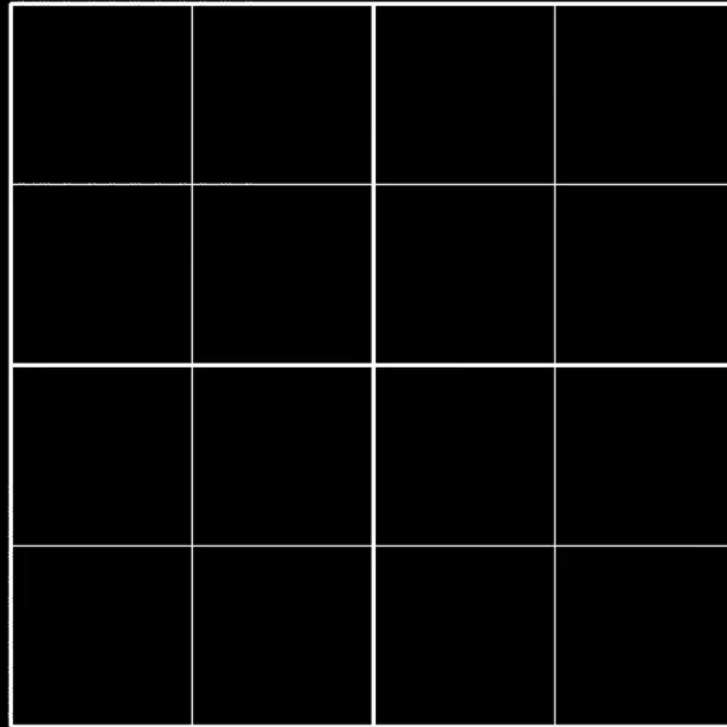
# A loop is better than a line

Order 1 Pseudo-Hilbert Curve



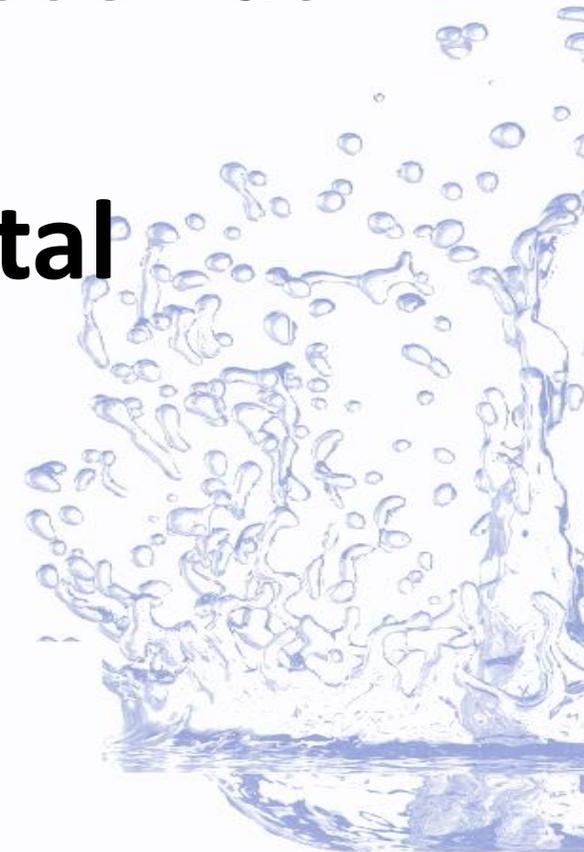
# After a loop, multiple loops?

Order 2 Pseudo-Hilbert Curve



# How to proceed?

- Idea: traverse space by «staying close» **at all scales.**
- Solution comes from maths: a **fractal curve.**
- We are using a **Hilbert curve.**

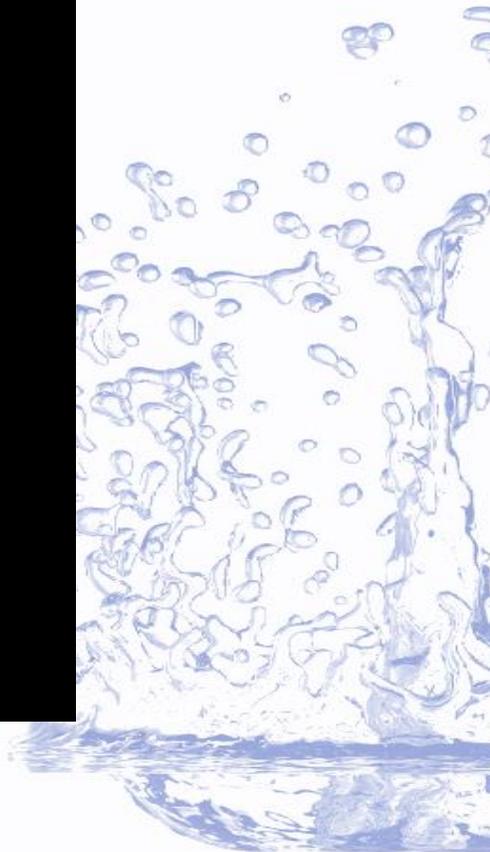
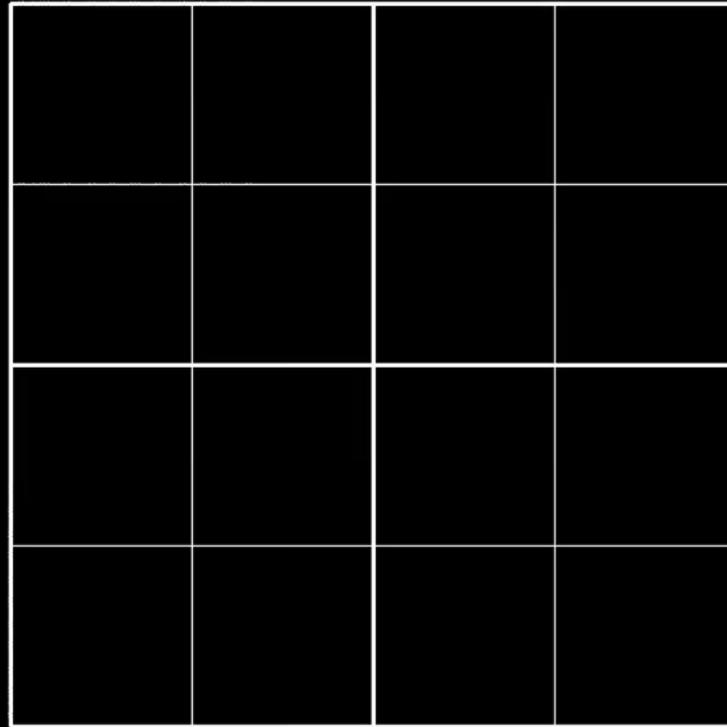






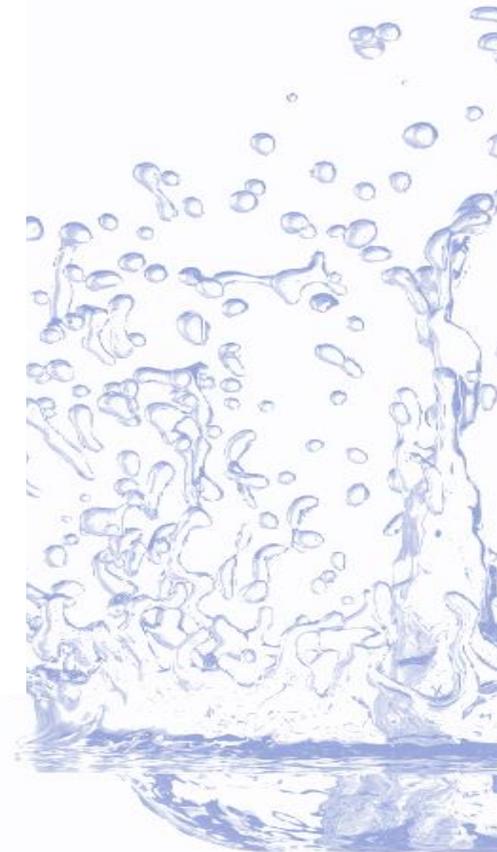
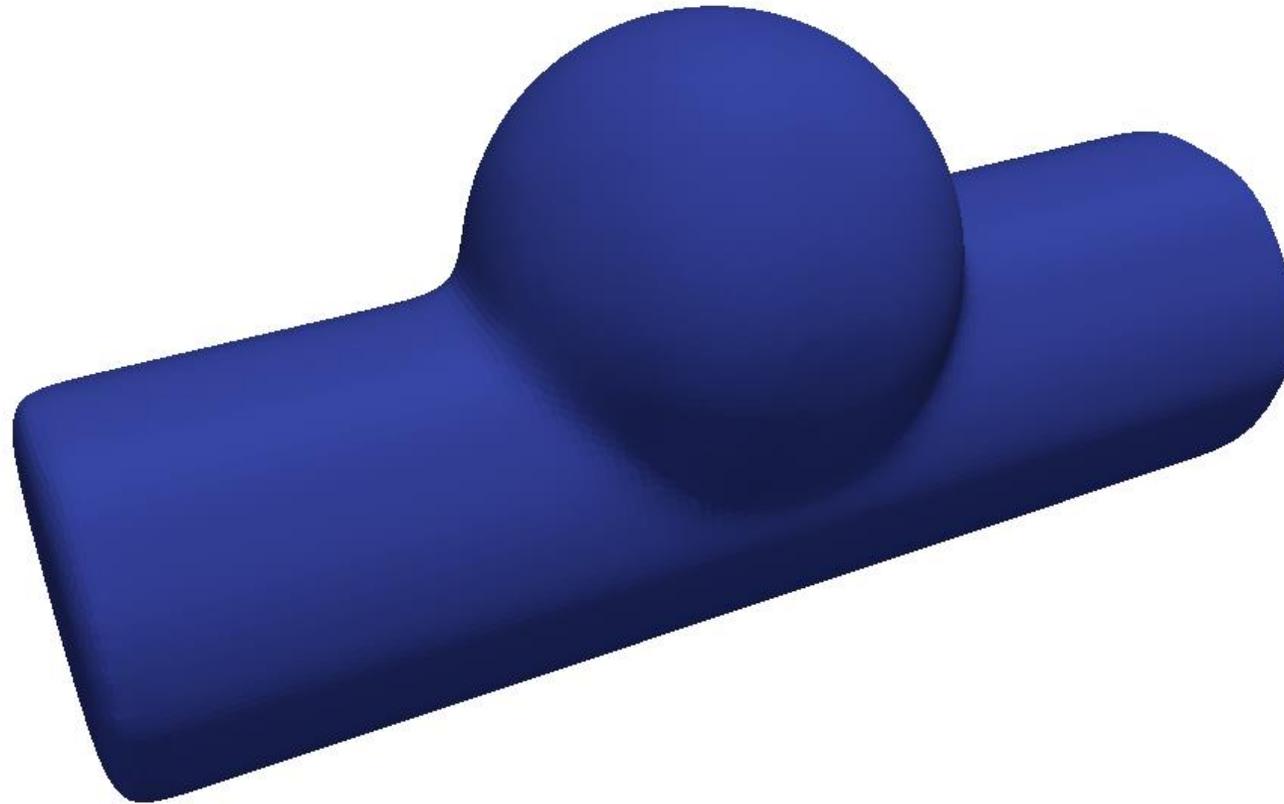
# Hilbert curves

Order 3 Pseudo-Hilbert Curve

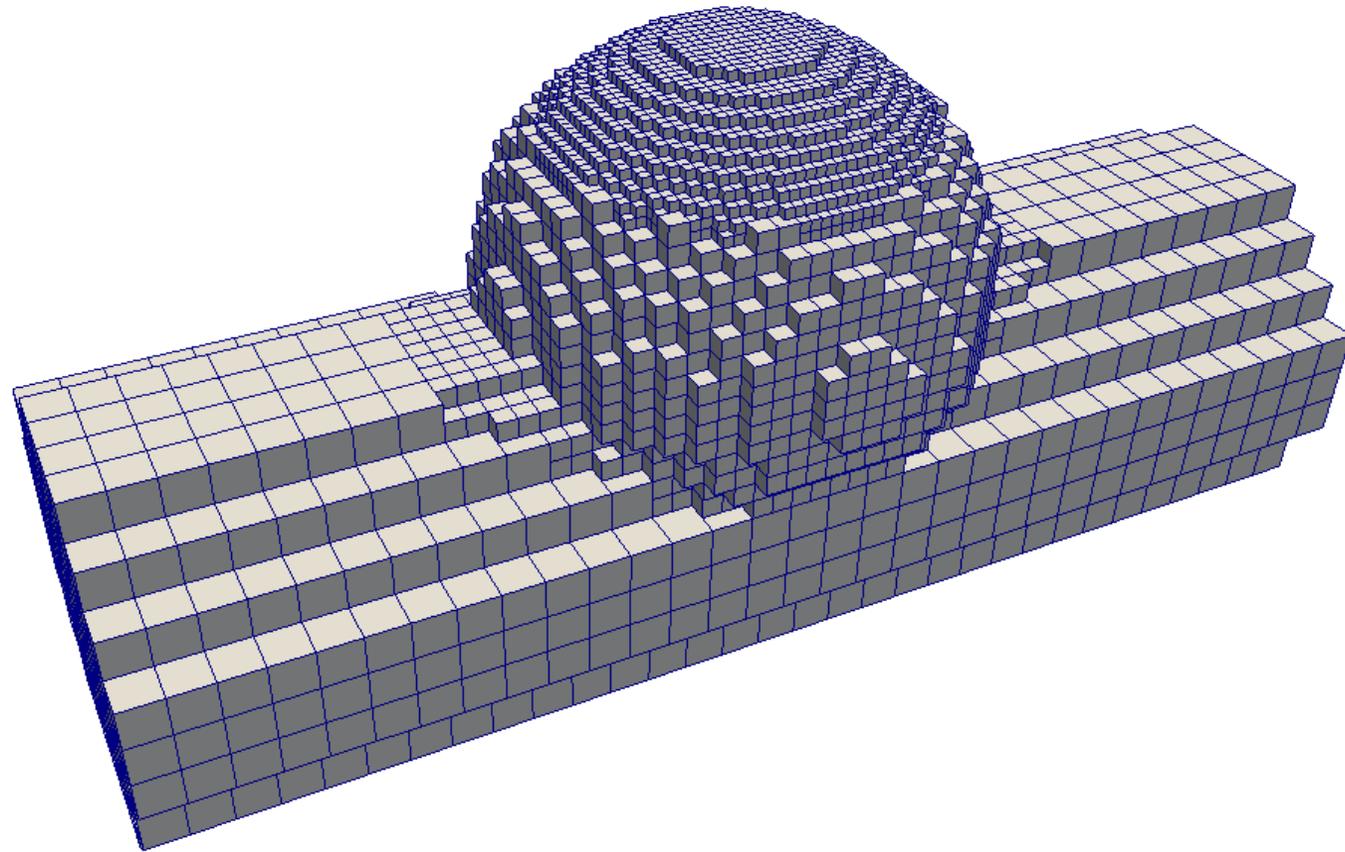




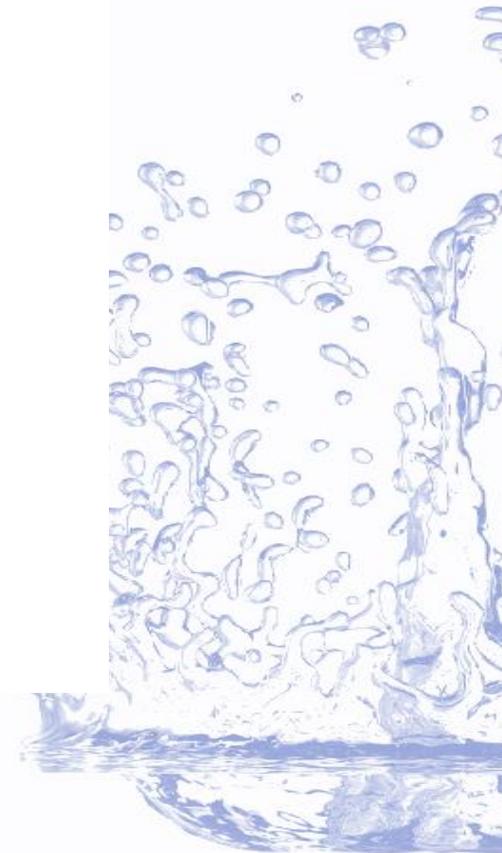
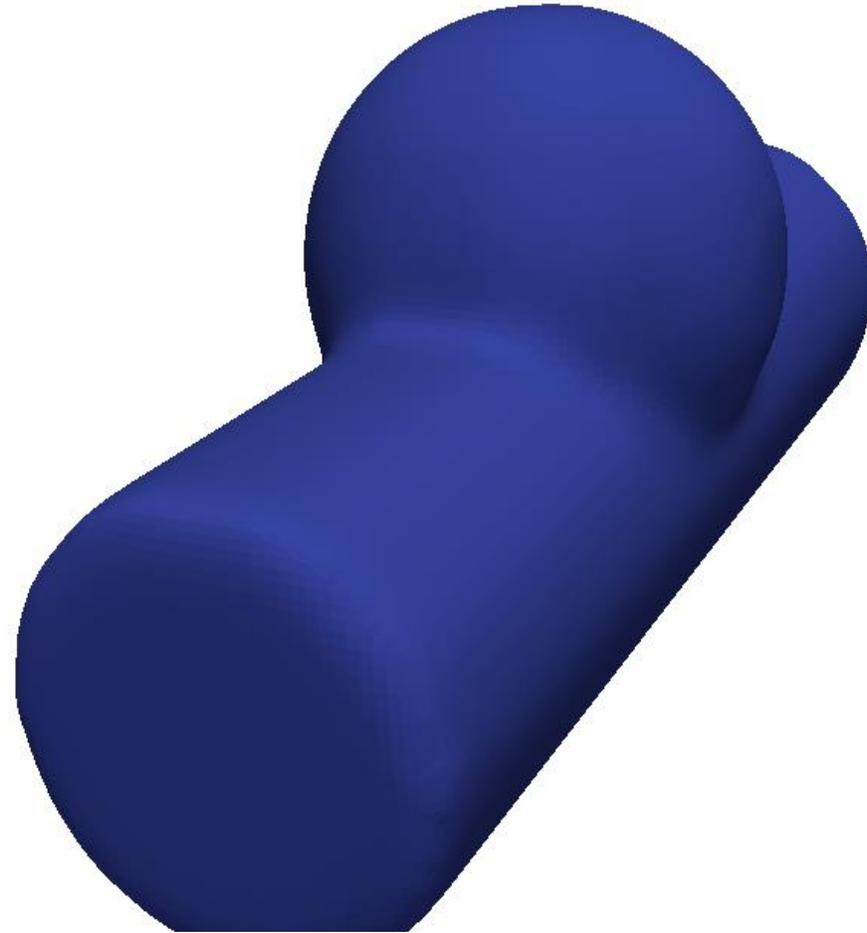
# 3D Hilbert curves



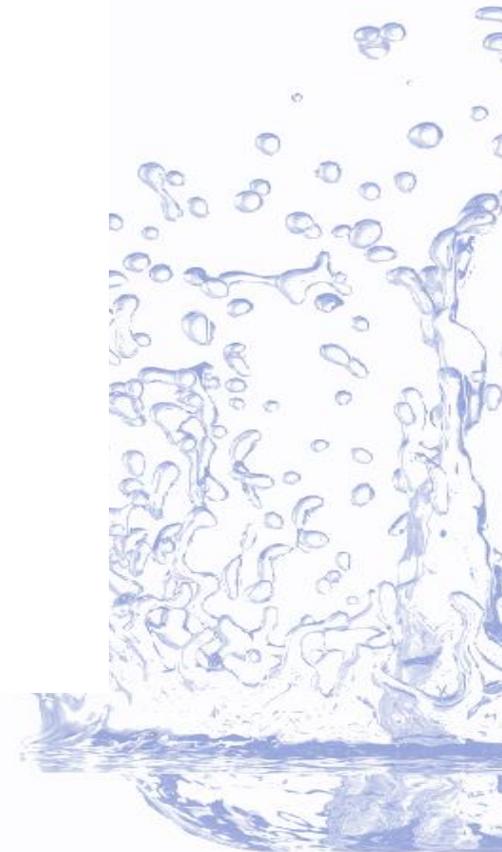
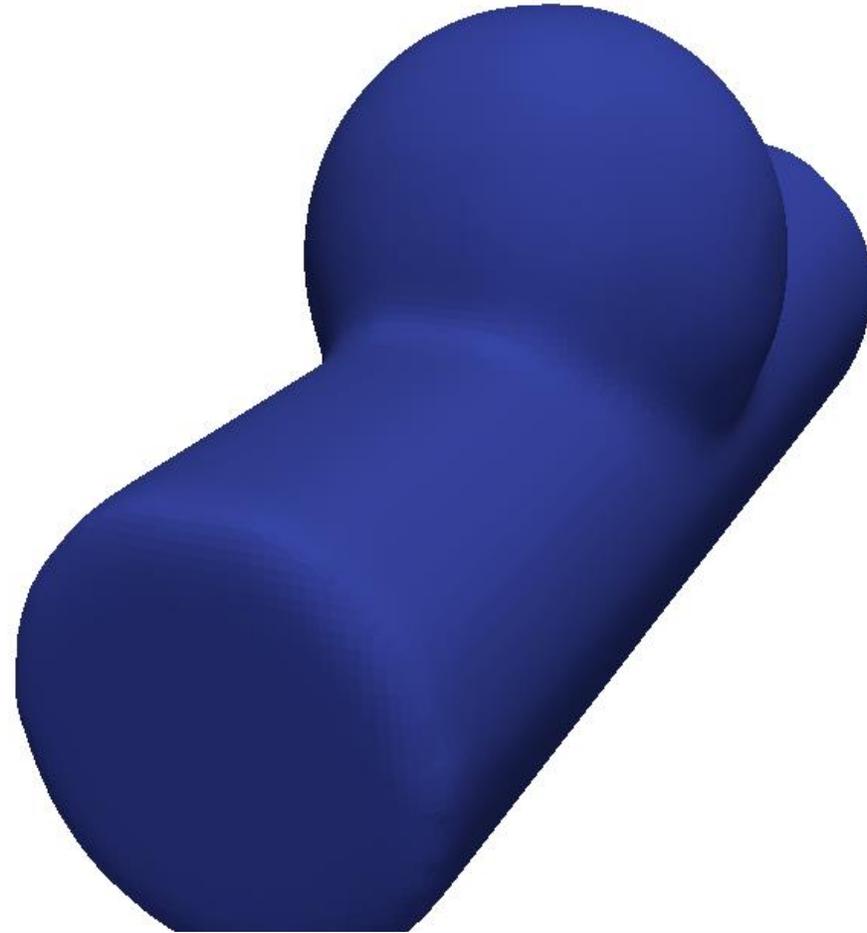
# 3D Hilbert curves



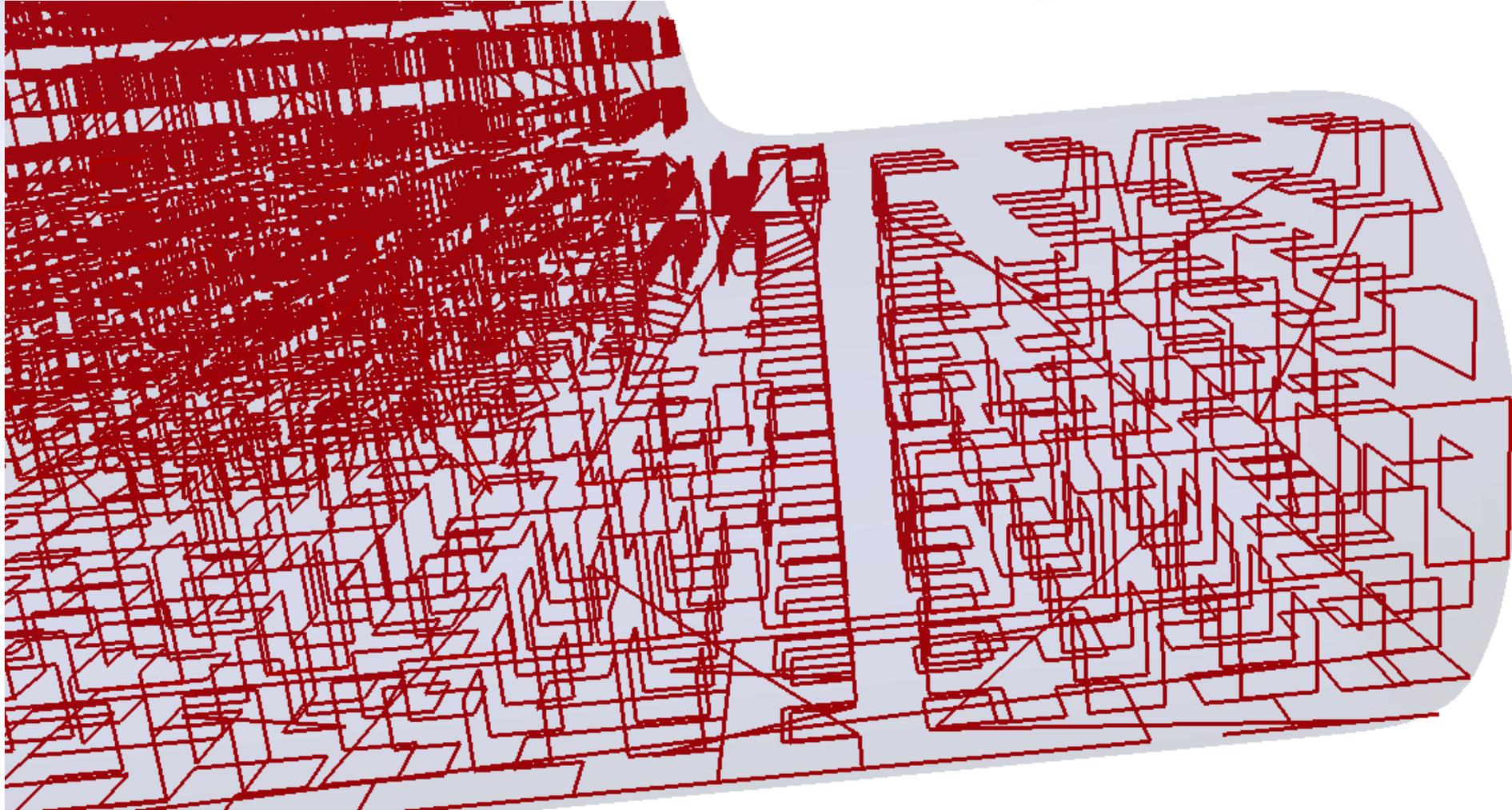
# 3D Hilbert curves



# 3D Hilbert curves

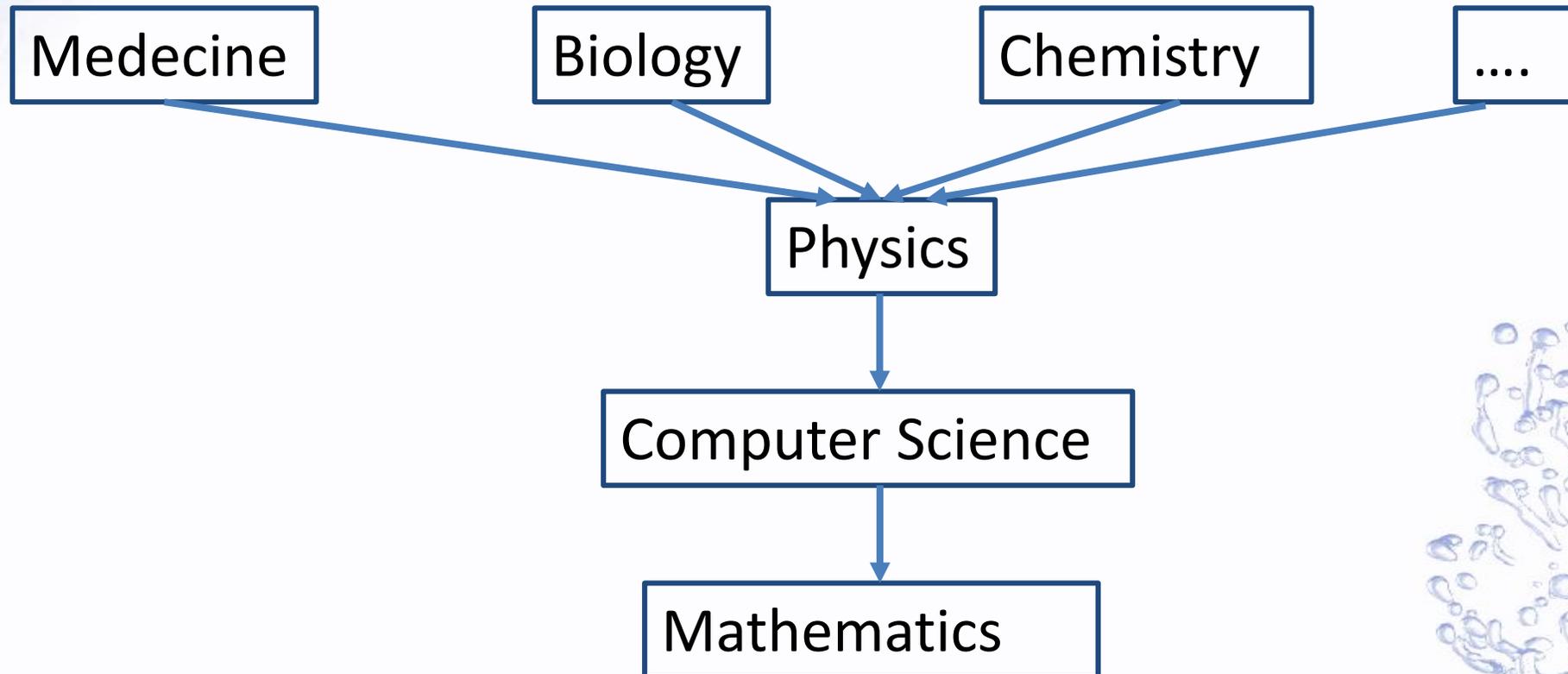


# 3D Hilbert curves





# Knowledge required for numerical model



# Computational science: intersection of multiple disciplines

- In modern science, procedures are **multi-disciplinary**.
- Computer science adopts methods from multiple domains.

