Efficient Algorithms for Flood Risk Analysis

March 29, 2017

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DABAI

Societal Challenge

Flood risk important societal challenge

- Cost of 2011 Copenhagen flood over 1 billion dollars

Copenhagen 2011

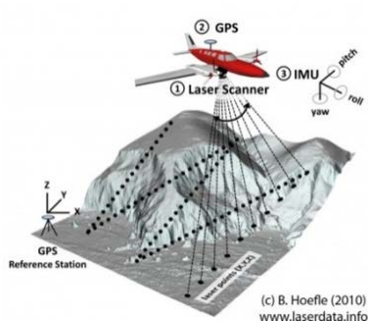
Aarhus 2012

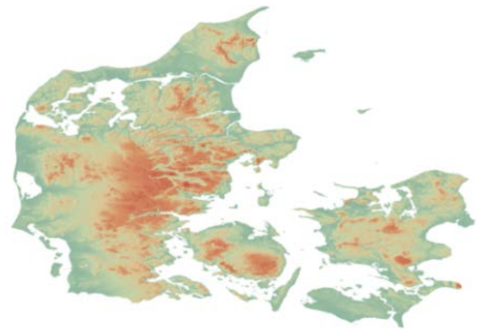
- Danish population (Userneeds)
  - 50% worry about their homes being flooded
  - 90% say high flood risk affect decision to buy house

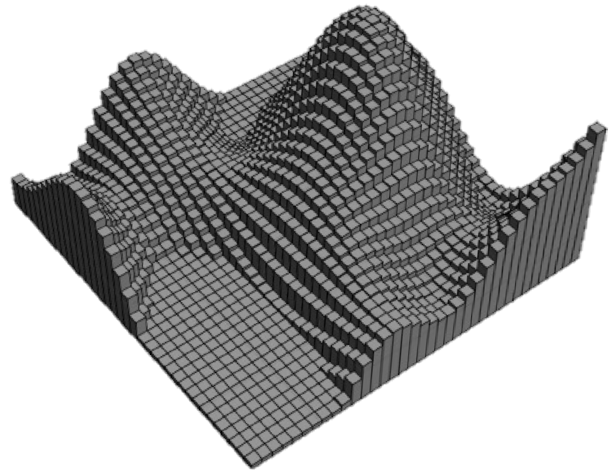
Public Big Data

Precise and detailed national terrain model

- At least 4 measurements per m^2







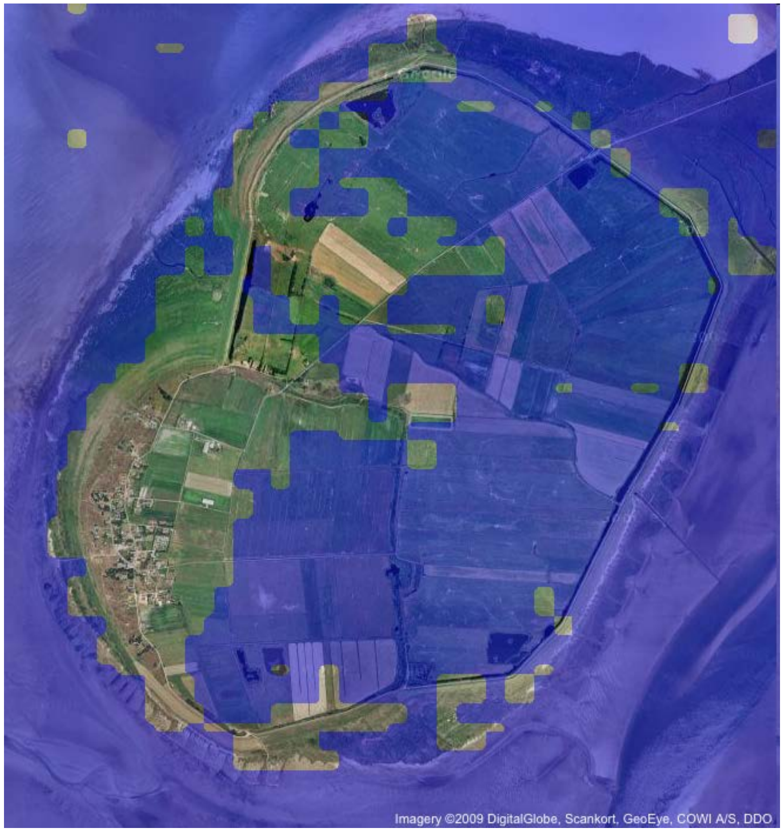
Freely available in base data program

Important basis for flood risk analysis

- Terrain essential for water flow
- Thousands of points in family home lot

Detailed Terrain Data Essential

Sea-level rise (2 meter effect on Mandø)

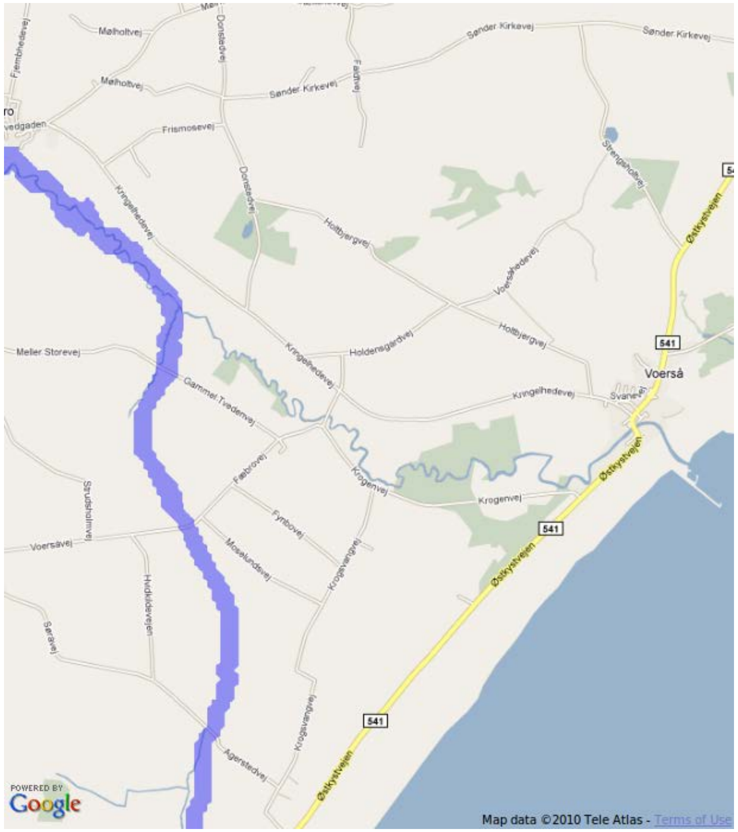


90 meter terrain model

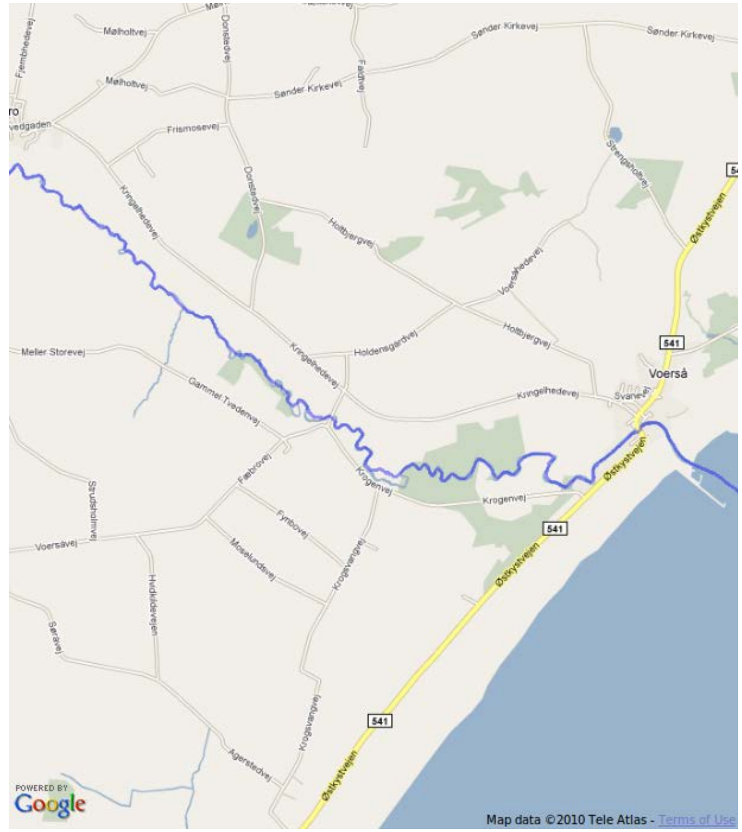
2 meter terrain model

Detailed Terrain Data Essential

Drainage network (flow accumulation)



90 meter terrain model

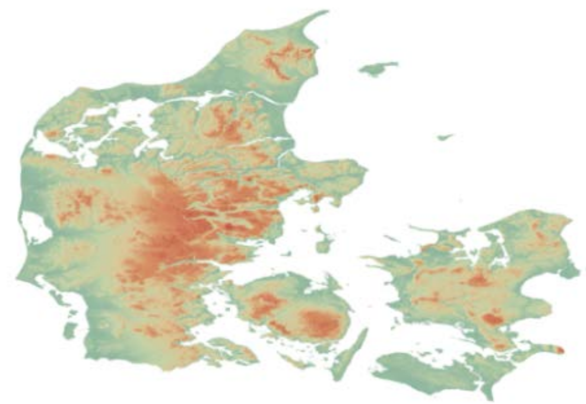


2 meter terrain model

Difficult to Handle BIG Detailed Data

Detailed terrain data BIG

- Denmark (42.000 km^2) ~168 billion measurements
- Aarhus ~2 billion measurements



Most analysis software cannot handle such BIG datasets!

Typical workarounds:

- Tiling (difficult and cumbersome)
- Data simplification (unreliable results)
- Small areas (area identification, border conditions)

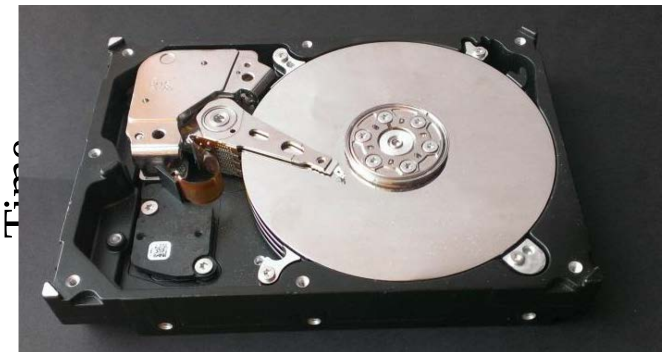
$\Rightarrow$ Hard to use detailed national terrain model even on regional scale

I/O-Efficient Algorithms

Disk often bottleneck when handling massive data

- Disk access is 10^6 times slower than main memory access

"The difference in speed between modern CPU and disk technologies is analogous to the difference in speed in sharpening a pencil using a sharpener on one's desk or by taking an airplane to the other side of the world and using a sharpener on someone else's desk." (D. Comer)



- Large disk access time amortized by transferring large data blocks

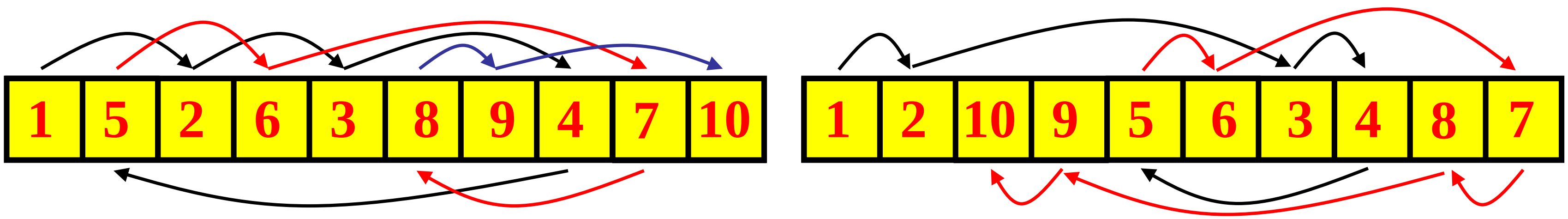
→ Important to store/access data to take advantage of blocks

I/O-efficient algorithms:

- Move as few disk blocks as possible to solve given problem

I/O-Efficient Algorithms Matter

- Example: Traversing linked list (List ranking)
  - Array size N = 10 elements
  - Disk block size B = 2 elements
  - Main memory size M = 4 elements (2 blocks)



Algorithm 1: N=10 I/Os   Algorithm 2: N/B=5 I/Os

- Difference between N and N/B large since block size is large
  - Example: $N = 256 \times 10^6$, $B = 8000$, $1ms$ disk access time

    $\Rightarrow$ N I/Os take 256×10^3 sec = 4266 min = 71 hr

    $\Rightarrow$ N/B I/Os take $256/8$ sec = 32 sec

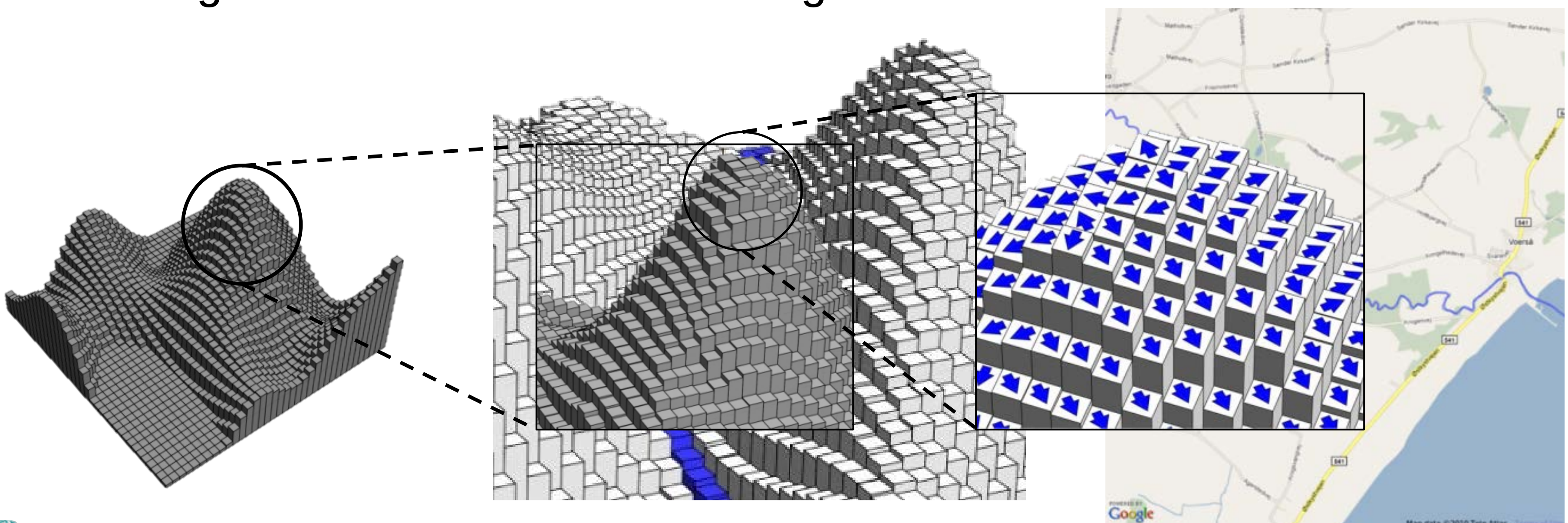
Surface Flow Modeling

Flow accumulation on grid terrain model:

- Initially one unit of water in each grid cell
- Water (initial and received) distributed from each cell to lowest lower neighbor cell (if existing)

⇒ Flow accumulation of cell is total amount of water through it

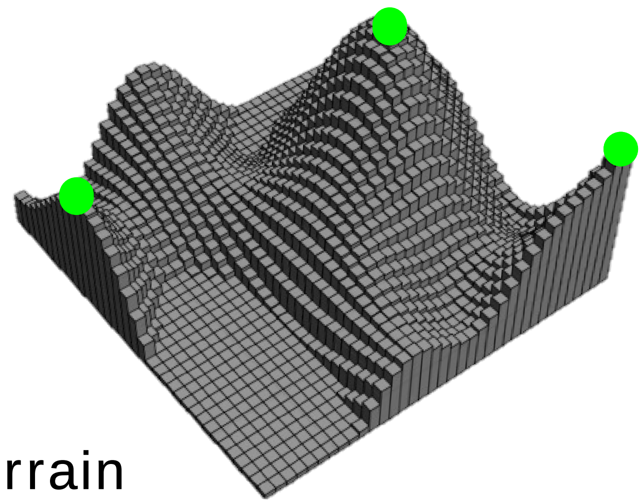
⇒ Drainage network = cells with high flow accumulation



Flow Accumulation Algorithm

Natural algorithm

- Sort cells by height
- Visit cells in height order and for each cell
  - Read height, height of neighbors and water amount
  - Add water to lowest neighbor



Problem: Disk access for each cell

- Almost same height cells scattered over terrain

$\Rightarrow$ Algorithm cannot handle Denmark model

Efficient Flow Accumulation Algorithm

Our I/O-efficient algorithm avoids scattered access by

- Data duplication
- "Lazy write"
  (using I/O-efficient priority-queue)

⇒ ~N/B I/O algorithm

⇒ Easily handle Denmark on normal desktop

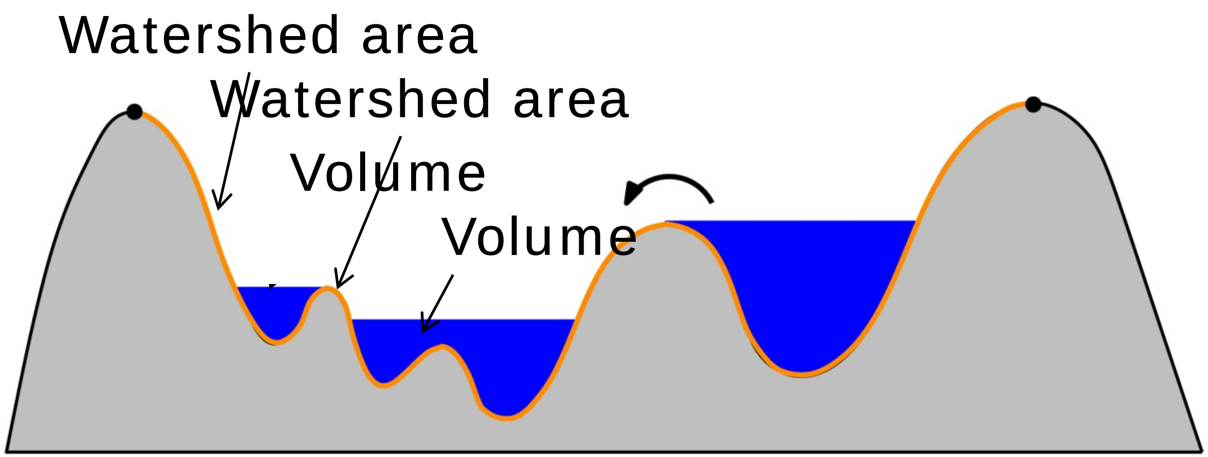
Several other I/O-efficient flood risk analysis algorithms have been developed

- E.g. event based flood risk

Depression Flood Risk: Flash Flood Map

Models how surface water gathers in depressions as it rains

- Water from watershed of depression gathers in the depression
- Depressions fill, leading to (potentially dramatic) increase in neighbor depression watershed size



Flash Flood Mapping:

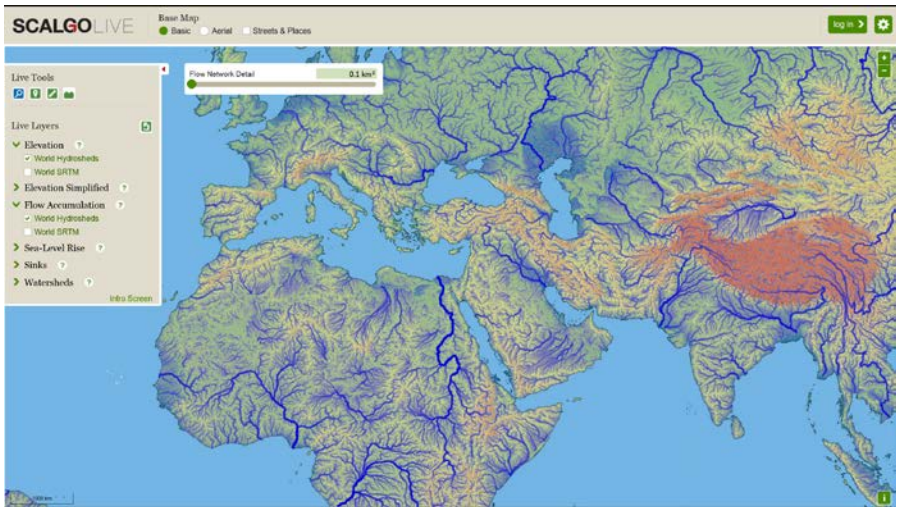
- Amount of rain before any given raster cell is below water

Commercialization

Flood risk algorithm technology commercialized by start-up SCALGO

Developed successful product SCALGO live

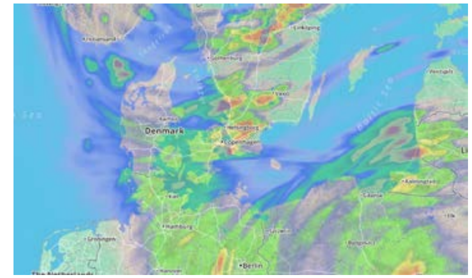
- Cloud based flood risk analysis platform
- Made possible by free data and algorithm technology
- Important interplay between efficient algorithms and visual analytics



DABAI Flood Risk Cases

The DABAI project will push BIG data flood risk analysis further

- Combining algorithms, visual analytics and machine learning technology
- Involving large number of partners



Currently four planned cases

1. ***Semi-automatic identification of hydrological corrections***
   - AU, DTU, KU, SDFE
2. ***Integration of forecast data with flood risk screening***
   - AU, DMI, SCALGO, SDFE, RM
3. Analysis updating after data update
   - SCALGO, SDFE, AU
4. River flood risk using integrated terrain and river data
   - COWI, NIRAS, SCALGO, SDFE, AU, RM

Thanks for your attention

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