An Individual Tree Simulator for Assessment of Forest Management Methods

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SUSWOOD project

- Sustainable and environmental friendly wood production for future industrial needs
- Cooperation between
  - Åbo Akademi University (High Performance Computing)
  - University of Joensuu (Forestry and Geographics)
- Financed by the Ketju Programme of Academy of Finland

SUSWOOD

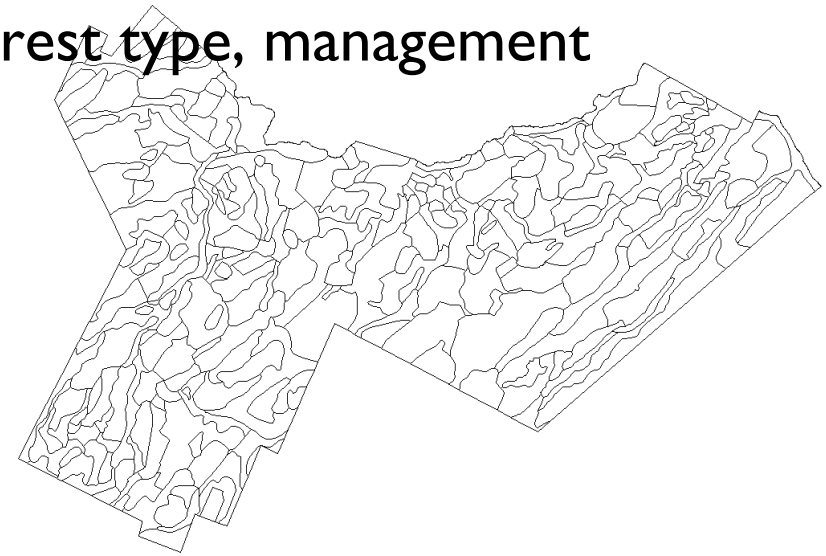
- Forest dynamics simulator
  - Simulates on single tree level
    - Calculates properties for each individual tree (position, diameter, age, height,...)
    - Trees compete with surrounding trees
  - Based on a stochastic mixed linear model
    - $Y = \underline{X}\beta + \alpha\tau + \gamma\xi + \varepsilon$

Simulation flow

- Start from an empty area (or predefined forest)
- Generate an initial forest stand
- Simulate forward in time (5 years steps)
  - Growth
  - Reproduction
  - Mortality
  - Management
- Calculate summary statistics

Simulation area

- The simulation area consists of multiple polygons
  - A polygon is the smallest area operated on
  - Each polygon can have separate parameters
    - Soil conditions, forest type, management methods



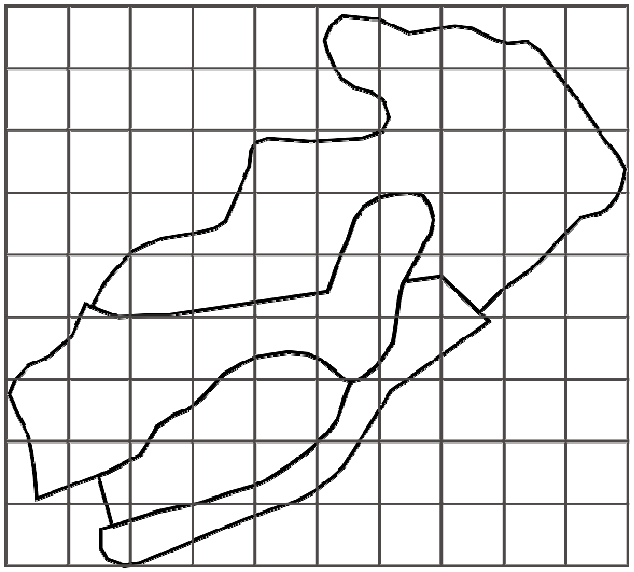
Tree interaction

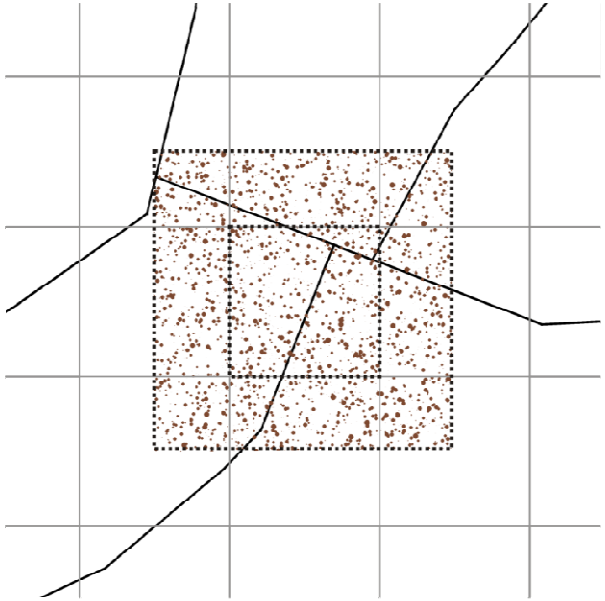
- Trees interact with neighbours
  - Independent of polygons
  - Necessary to efficiently find neighbours

- Place a grid over the simulation area
  - All trees that can interact with a tree in a cell belong to that cell
  - Only need to search for neighbours inside a cell

Tree grid

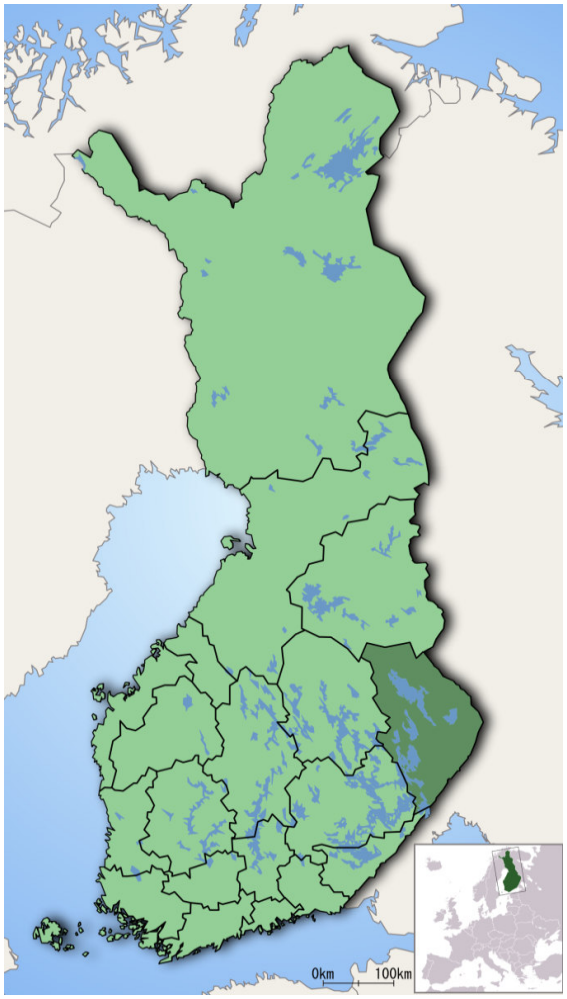
- Trees are placed in a cell according to position
  - Also placed in nearby cells if close to the border





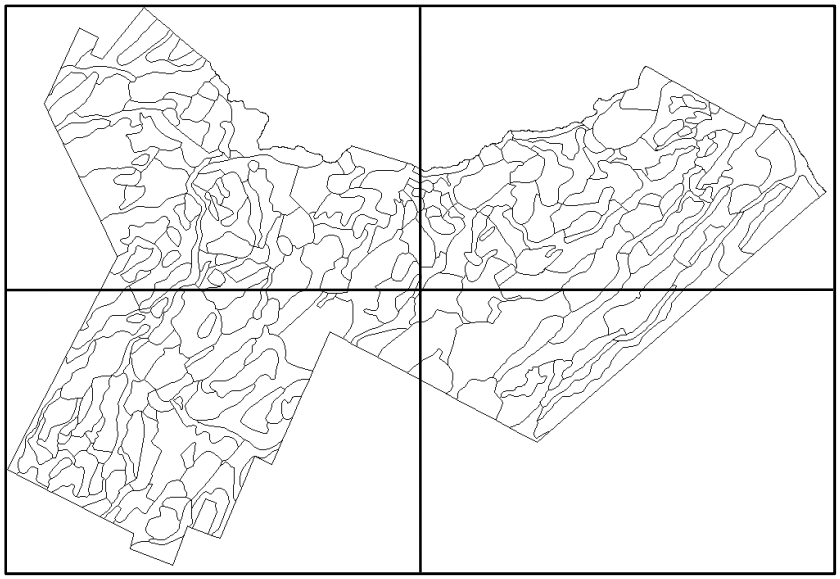
Large scale simulations

- Goal: Simulate North Karelia, Finland
  - 2 000 000 hectares semi dense (4000 trees / ha) forest
    - Roughly 8 000 000 000 trees
- Single processor version
  - 1 000 hectares
    - 4 000 000 trees



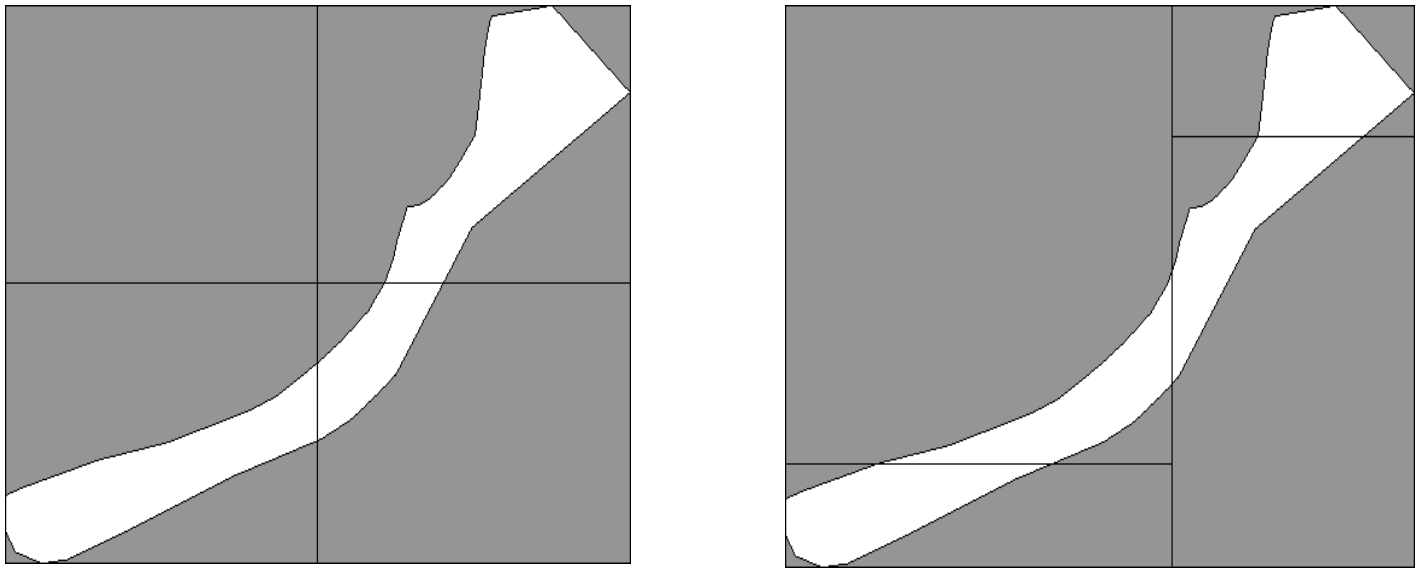
Parallel implementation

- Domain decomposition done independent of polygons
  - Complex decomposition algortihm
  - Simple communication algorithms



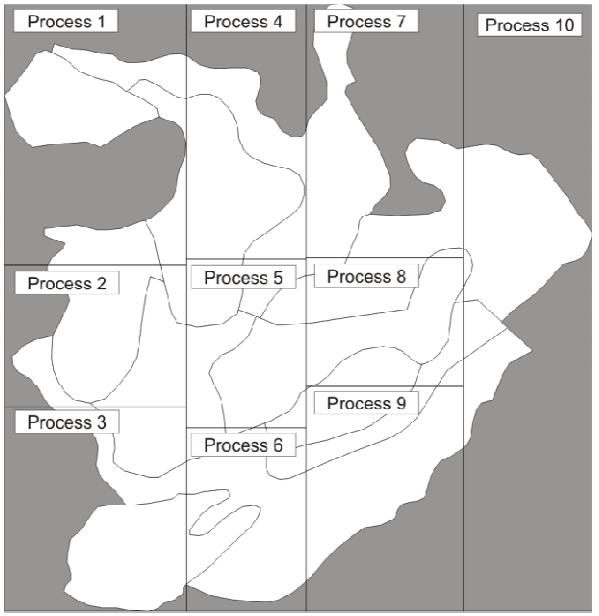
Load balancing

- Need to ensure processes have equal amount of work
- Decomposition based on area
  - Use active area (polygons) and not bounding box



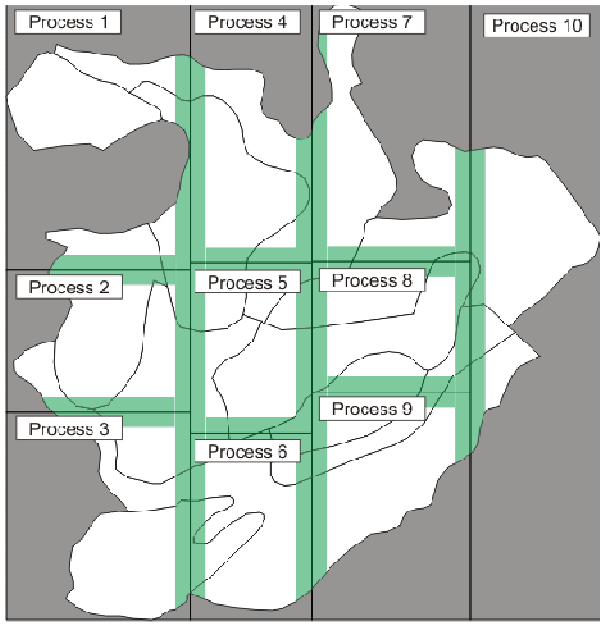
Decomposition implementation

- Number of columns and rows to divide into is calculated
  - Based on number of processes
    - Not limited to 2^N processes
  - Based on original aspect ratio
- Each process finds its own area
  - Uses binary search to find boundaries
    - First in x, then in y direction



Process communication

- Communication only between neighbours
- Each process broadcasts its coordinates
  - Other processes become aware of their neighbours
- Information about trees close to process borders is communicated once in each iteration



Performance

- Sequential implementation
  - Memory usage limits simulation size
    - Proportional to the number of trees
  - With 1GB of memory it is possible to simulate 1 000 hectares with 4 000 trees/ha
    - Simulation time 2 min
    - Statistics calculation 30 min

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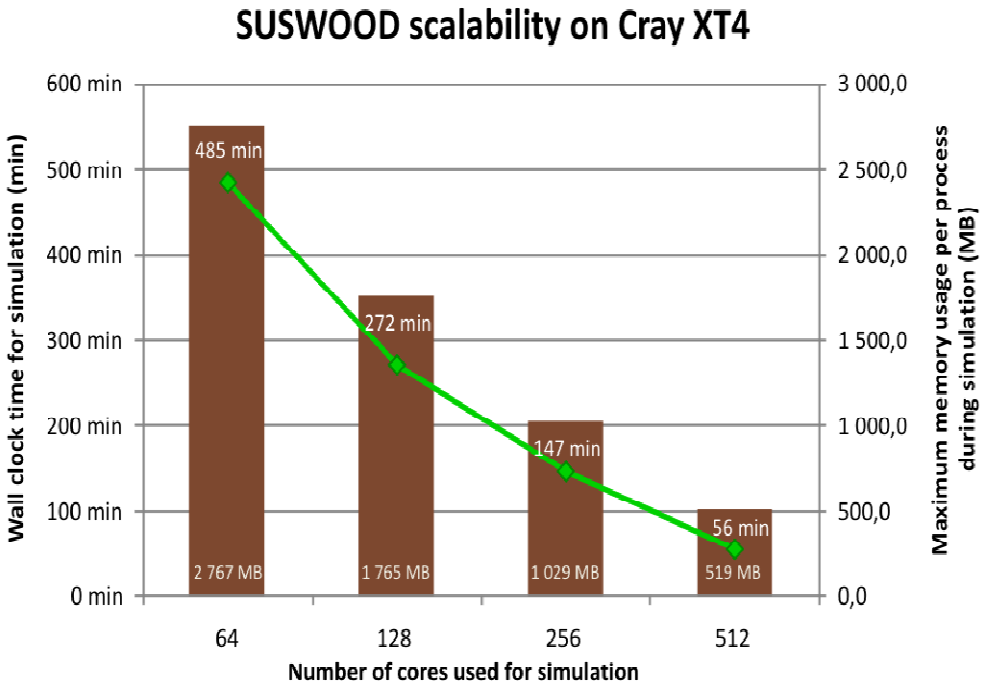
Performance

- Parallel implementation
  - Using 512 cores we have simulated roughly 300 000 hectares with 1 billion trees
    - 1 GB memory / core
    - Total runtime 55 min

Scalability

- Designed for large scale simulations
  - Scales up to 512+ cores



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Conclusions

- A very large scale individual tree forest simulator
  - Scales up to 512+ cores, billions of trees
- Can be used as a tool to optimize forest management
  - Able to use real forest data as input
    - Acquired nowadays by remote sensing
- The simulator will be released as open source

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Thank you for your attention!