Project Ideas in Computer Science

Keld Helsgaun

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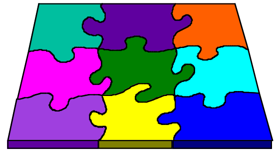


Research:

- Combinatorial optimization
- Heuristic search (artificial intelligence)
- Simulation

Teaching:

- Programming, algorithms and data structures
- Computer architecture, networks
- Parallel programming

Headlines

- Algorithms Inspired by Nature
- Planning
- General Problem Solving
- Game Programming
- Parallel Programming
- Optimization Art

Evolutionary computation

Starting about 3.5 billion years ago with bacteria, nature embarked on the grandest of all algorithms: the evolution of highly complex and dynamic machines capable of interacting with and adapting to their environments in order to solve problems.

We know these machines as plants and animals.

Genetic algorithms

Darwin's principle of evolution ("survival of the fittest") may be used to construct effective optimization algorithms

Genetic algorithms

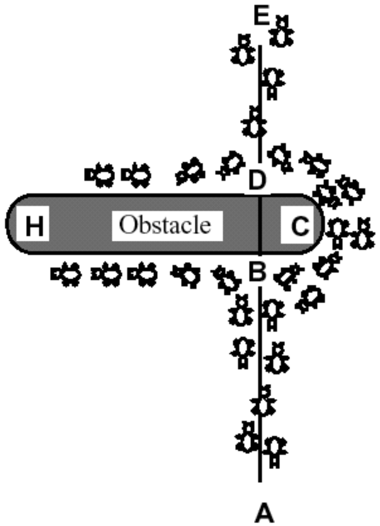
An **individual** (**chromosome**) represents a candidate solution for the problem at hand.

A collection of individuals currently "alive", called **population** is evolved from one **generation** to another depending on the **fitness** of individuals, indicating how fit an individual is, in other words, how close it is to an optimal solution.

At each evolutionary step, **crossover** and **mutation** (genetic operators) are applied on individuals.

Swarm intelligence

Social insects - such as ants and bees - give us a powerful metaphor for developing decentralized problem solving systems consisting of simple **co-operating agents**.



Ant colony optimization

Each ant leaves a trail of pheromones when it explores the solution landscape. This trail is meant to guide other ants.

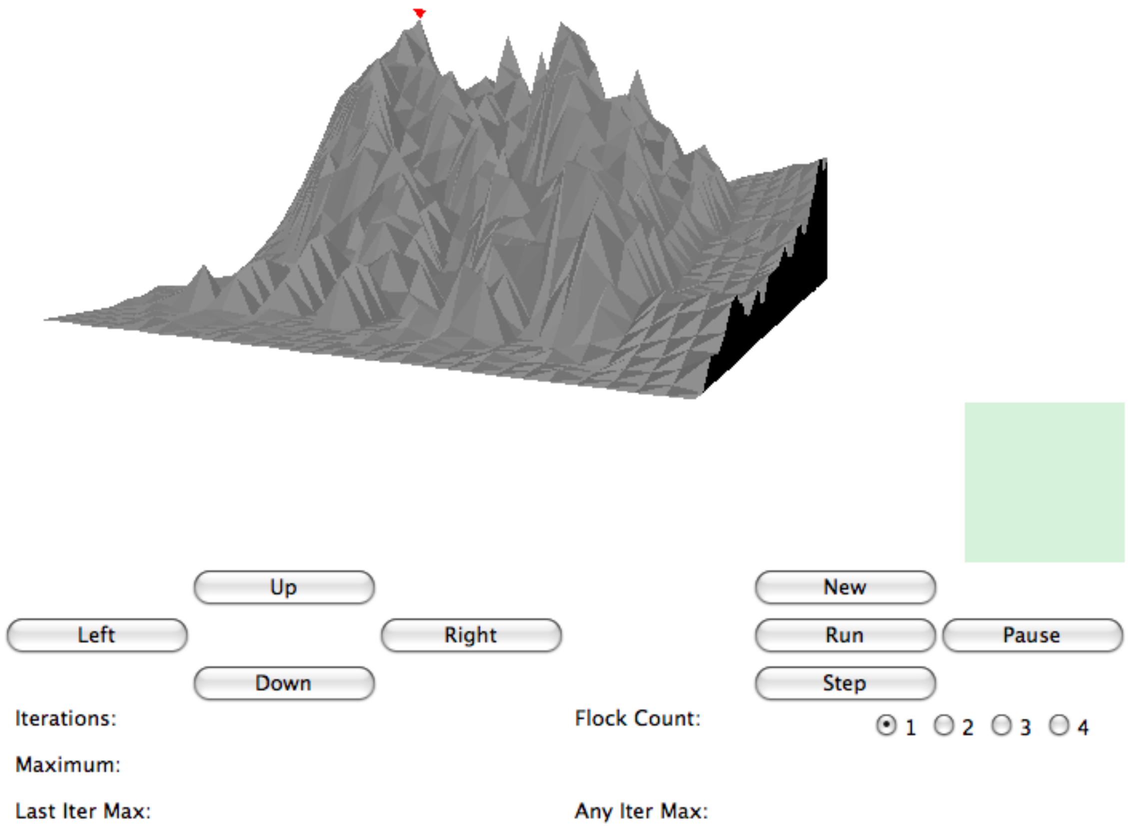
The trail will be taken into account when an ant chooses the next location to move to, making it more prone to walk the path with the strongest pheromone trail.

Flock intelligence

1. Birds want to fly toward some focal point, like a place to land.
2. Birds want to stay close to other birds, but not too close.
3. Birds want to fly at a constant speed if they can.
4. Random events like wind gusts can interfere with flight.


Controls
Green Birds
Blue Birds
Red Predators
Number Birds
Speed
Max Turn
Reset
Detection Distance
Predator Hunger
Show Dist Rang
Separate To Avoid Dist

Flock.html



FlockVisualization.html

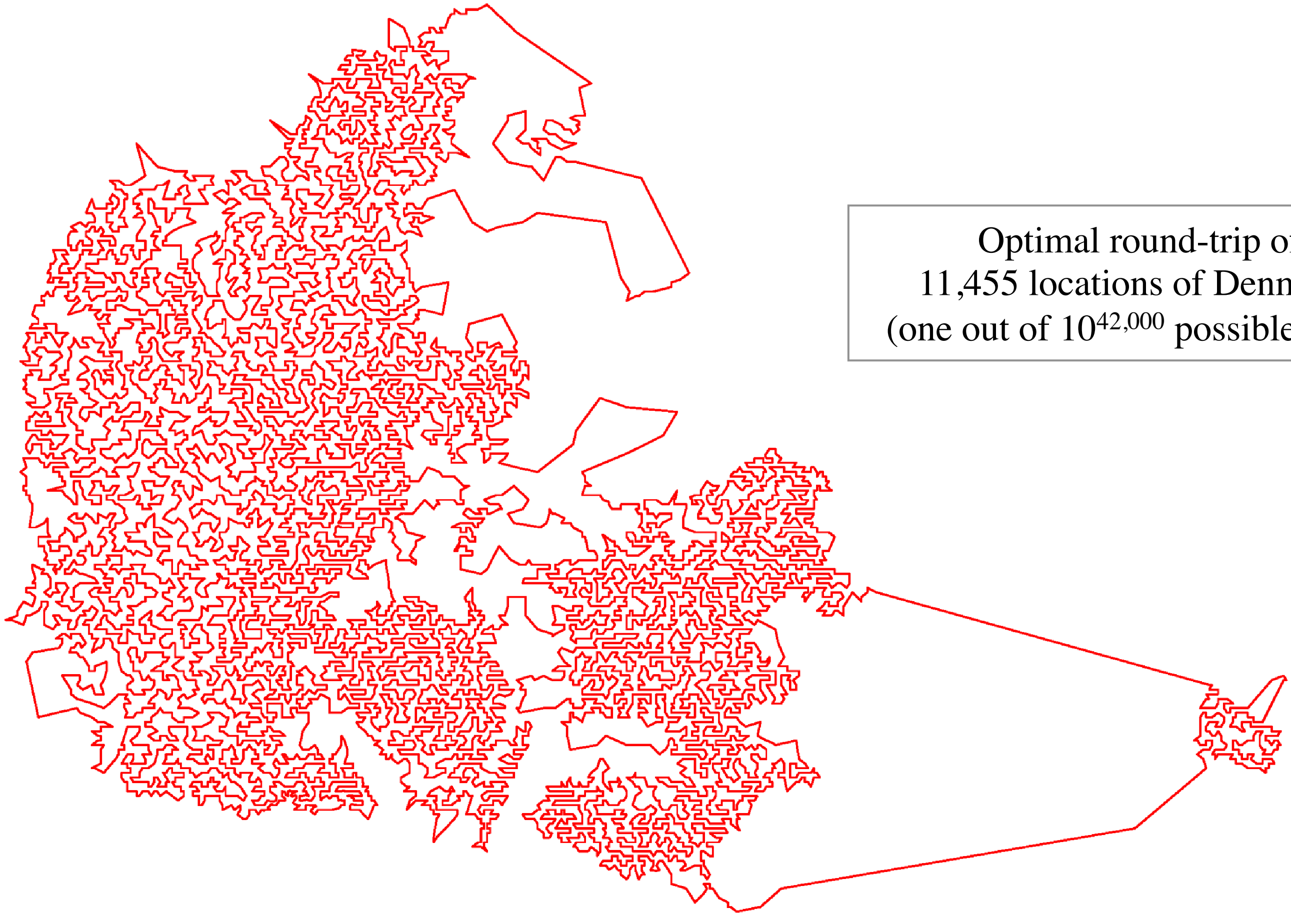
Timetabling

Assign a number of events to a limited number of time periods.

Course planning: Assign each lecture to some period of the week in such a way that no student is required to take more than one lecture at a time.

International Timetabling Competition:
http://www.idsia.ch/Files/ttcomp2002/

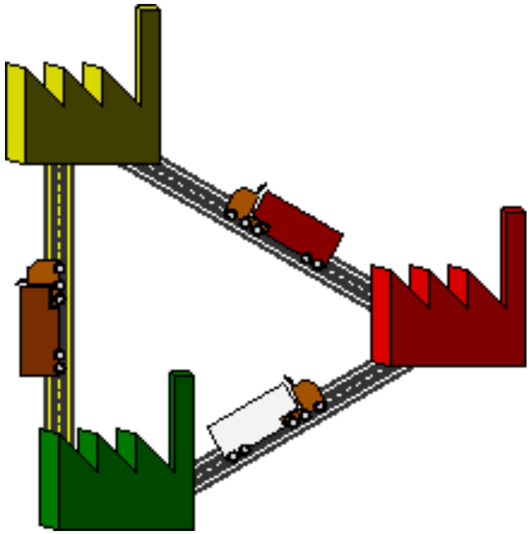
The Traveling Salesman Problem



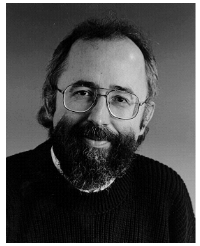
Optimal round-trip of
11,455 locations of Denmark
(one out of $10^{42,000}$ possible tours)

The Quadratic Assignment Problem

Given a set of n locations and a set of n facilities. The problem is to assign all facilities to different locations with the goal of minimizing the sum of the distances multiplied by the corresponding flows.



The algorithmic beauty of plants

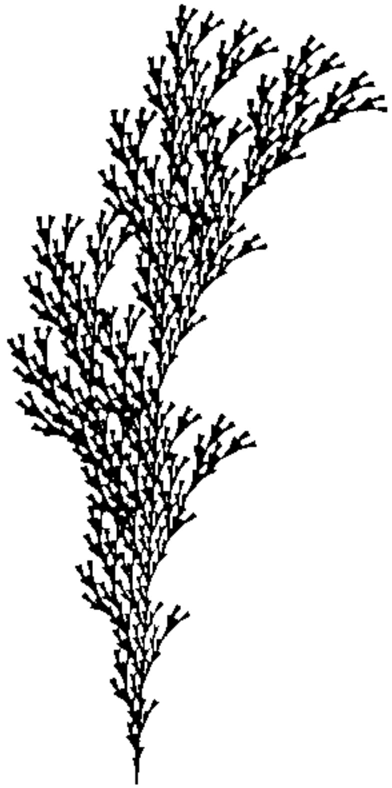


Prusinkiwicz

Lindenmayer systems (L-systems) provide and elegant notation for modeling and simulation of the development of plants.

Example:

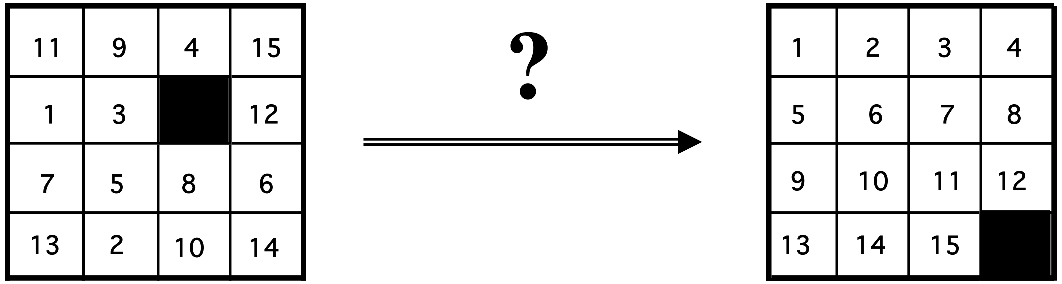
```
n = 4, d = 22°
F
F = F[+F]F[-F][F]
```



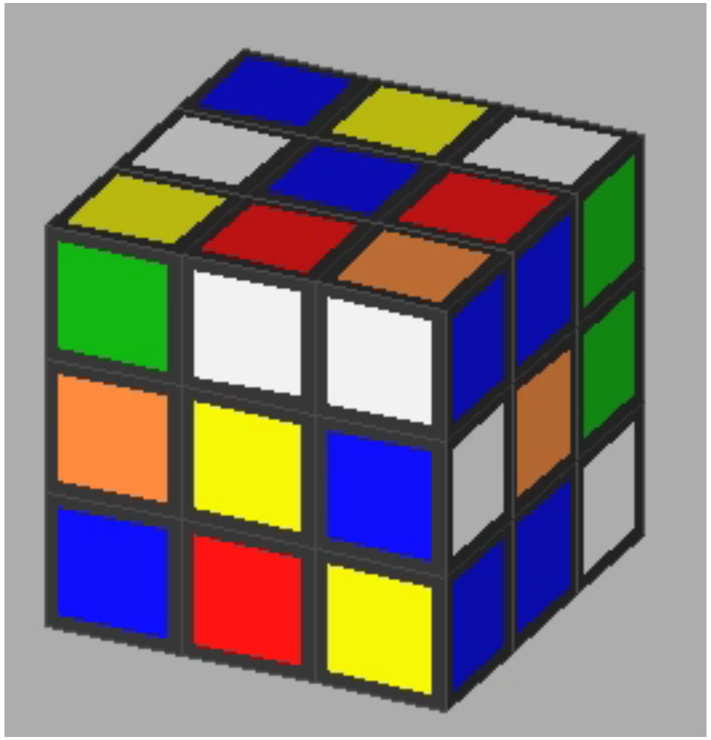
Problem solving

Write a Java framework for **general** problem solving.

For example, the package must be applicable to solving the so-called 15-puzzle:



Rubik’s cube

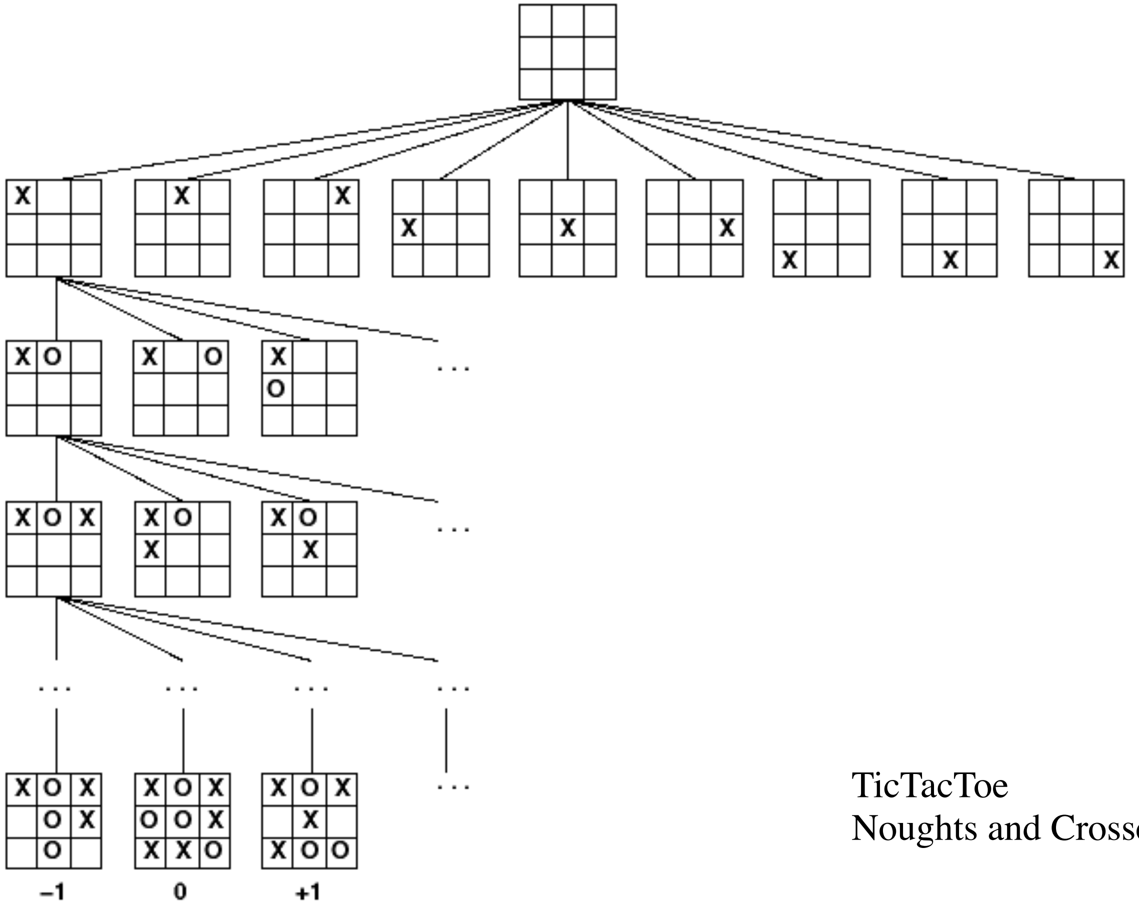


Tetroku

A hybrid Tetris Soduko game

A program for playing checkers

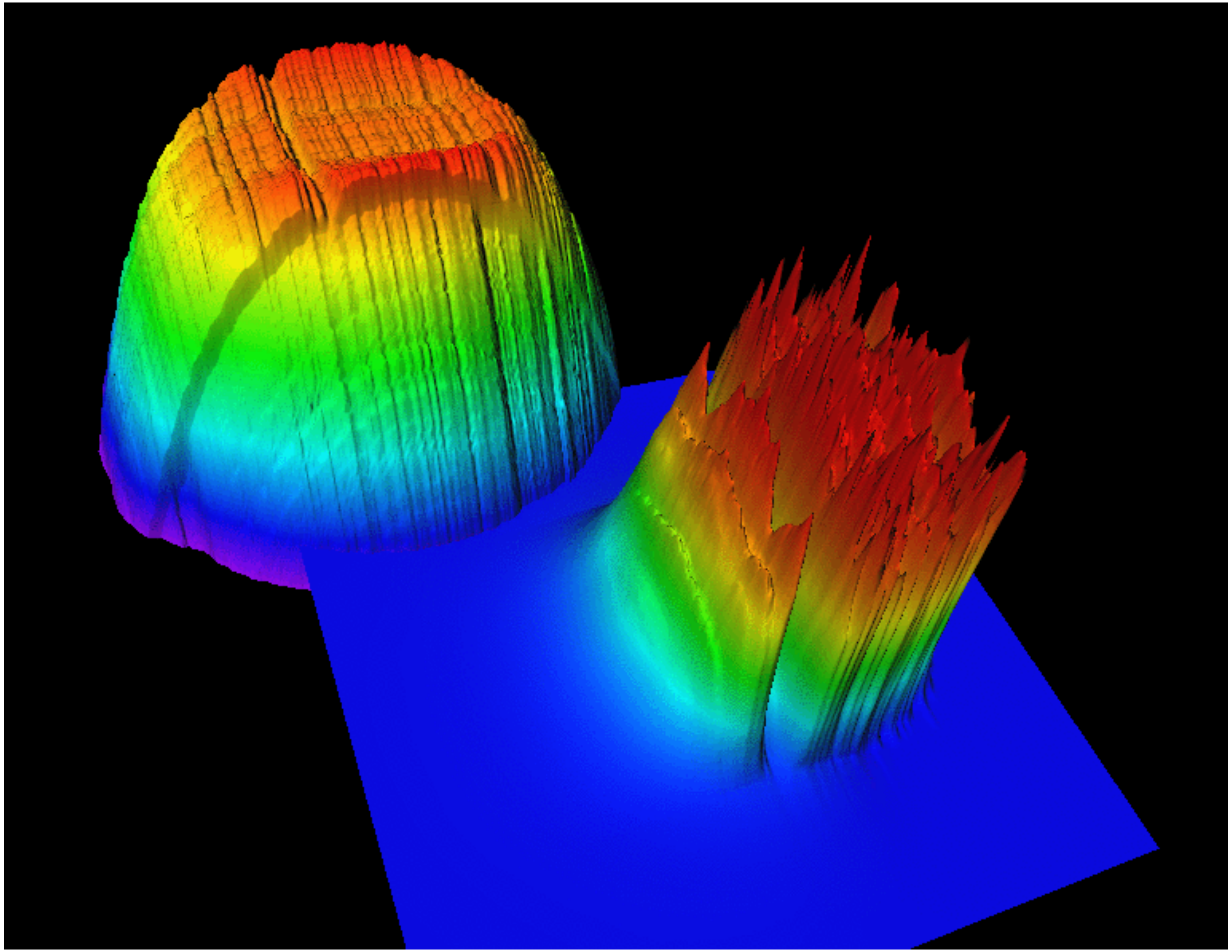
A framework for game tree algorithms



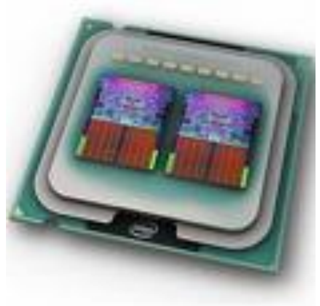
TicTacToe
Noughts and Crosses

Parallel Computing

Today, Parallel Computing is considered a standard method for scientists for solving problems in such diverse areas as simulation of galaxies, climate modeling, biological sequence analysis, and molecular dynamics.



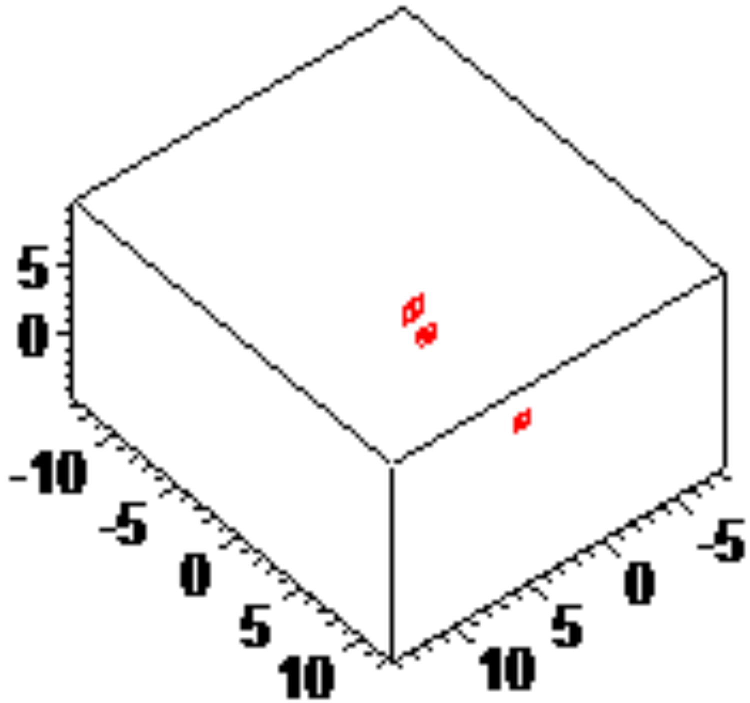
Parallel computing

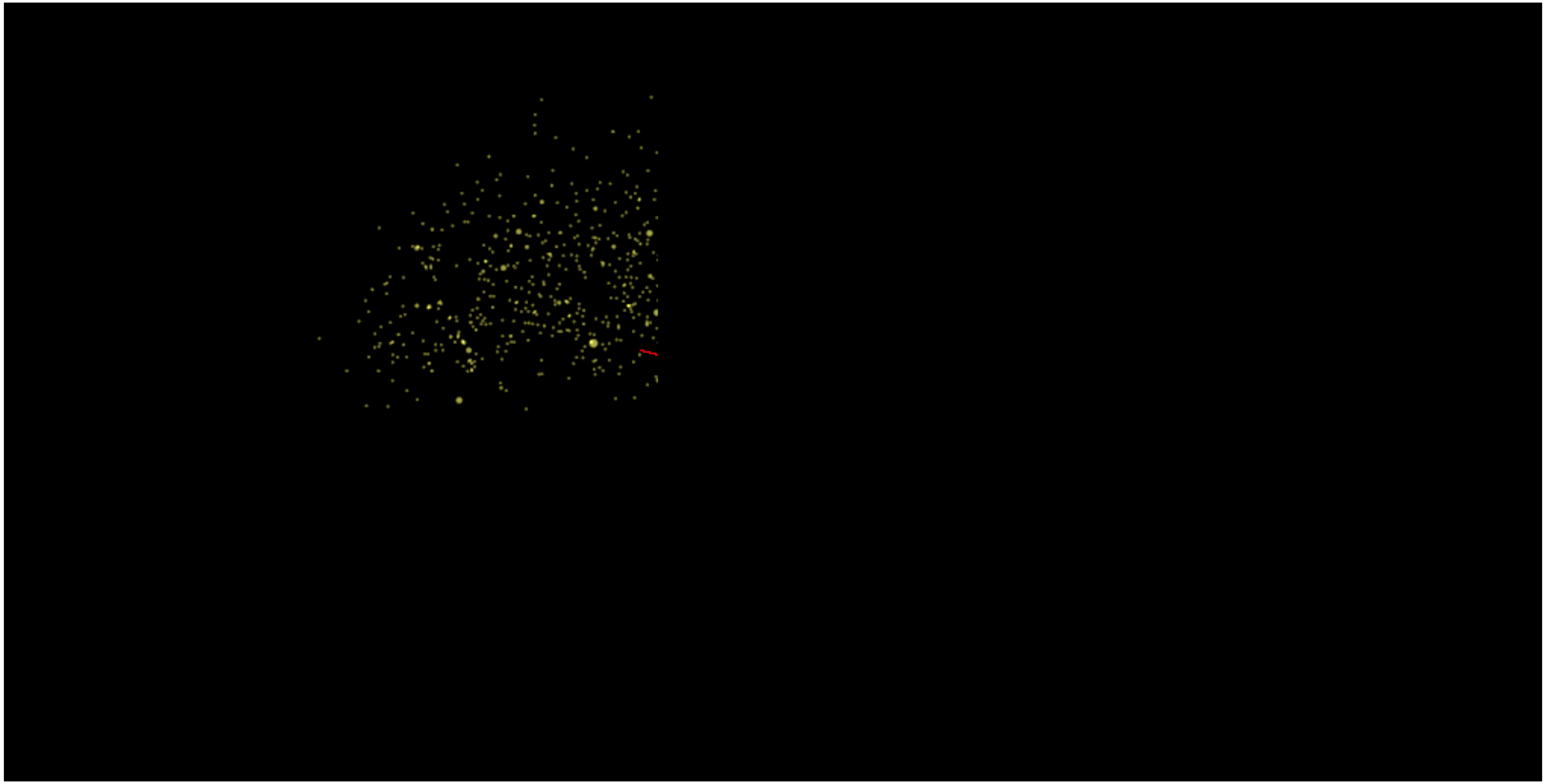


1. Java threads
2. Java Parallel Library
3. OpenMP
4. Cilk
5. Intel Concurrent Collections
6. CUDA (NVIDIA graphics cards, GPUs)
7. Cell programming (Playstation 3)

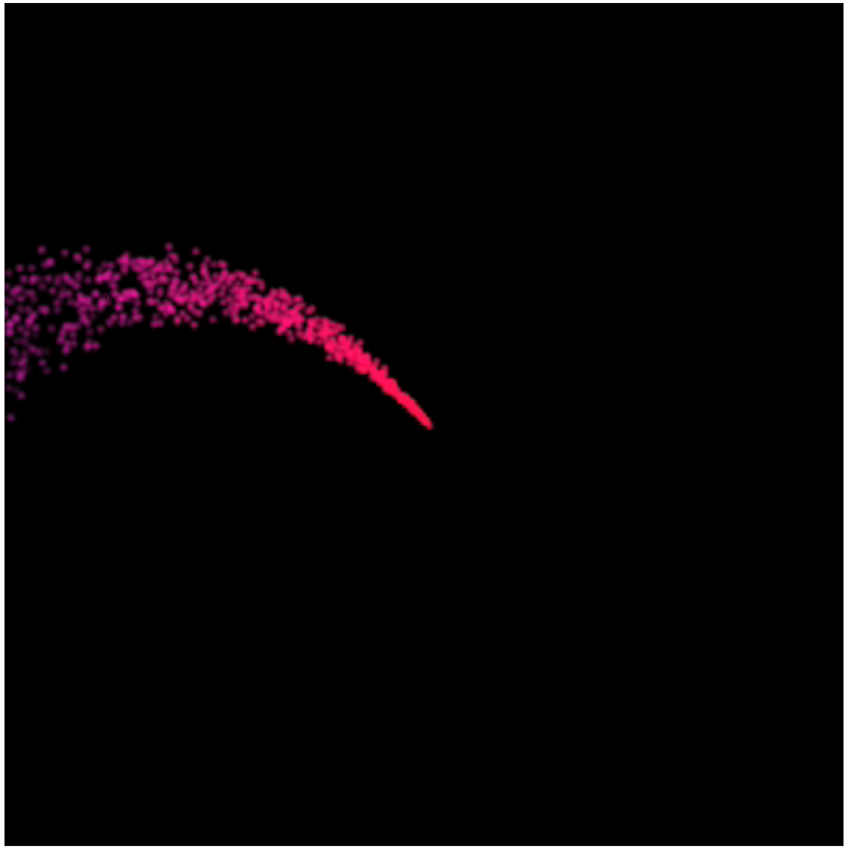
N-body simulation

Prediction of the movement of *N* bodies interacting according to Newton's second law.

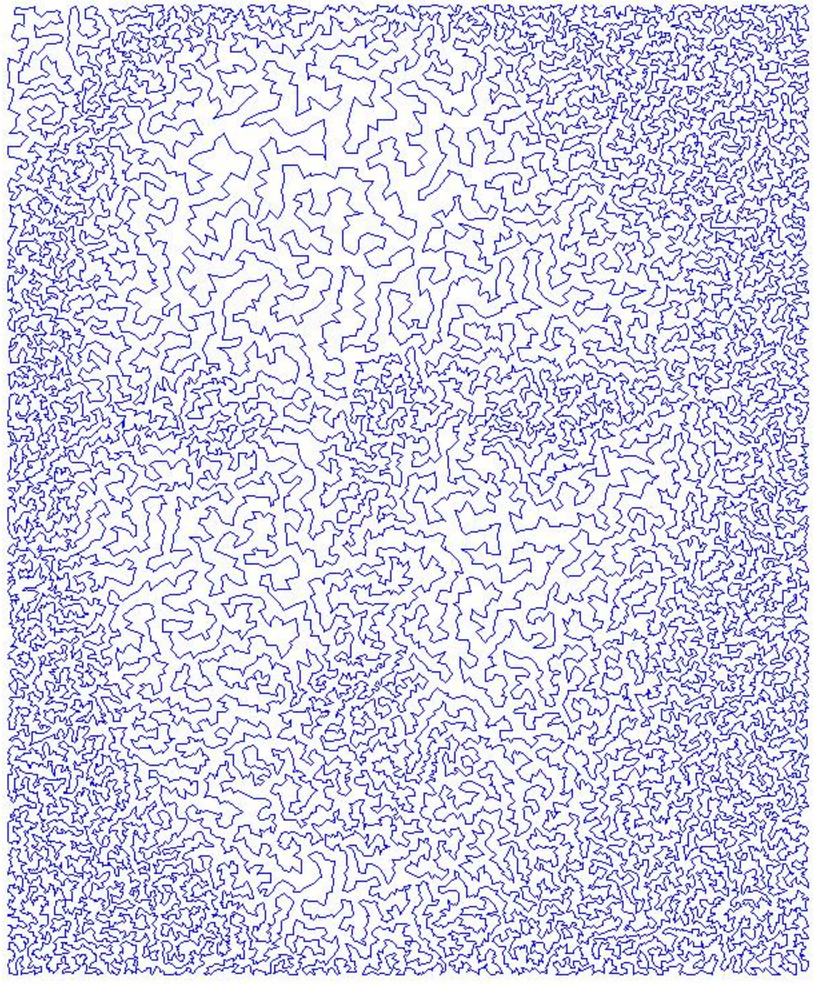




An API for particle systems



OPT-art

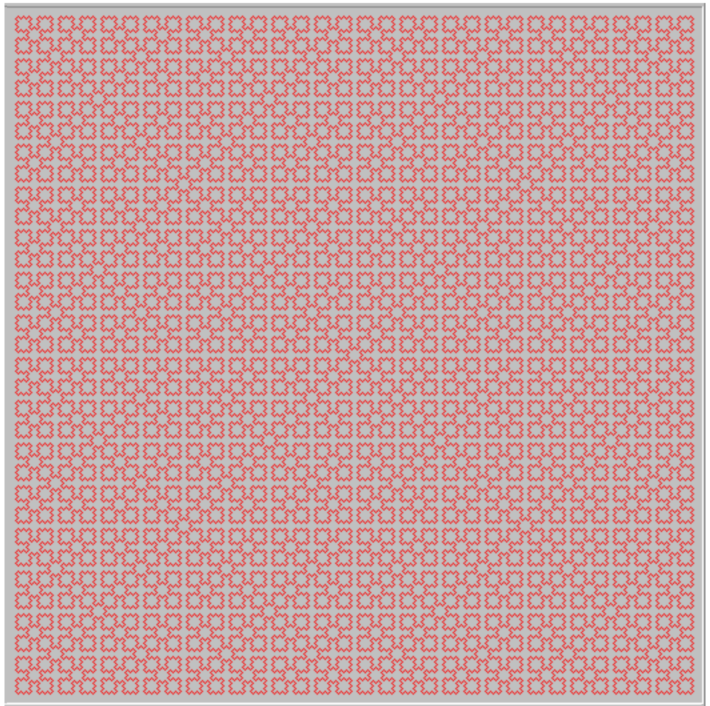


27,486 points

One out of $10^{110,079}$ possible tours

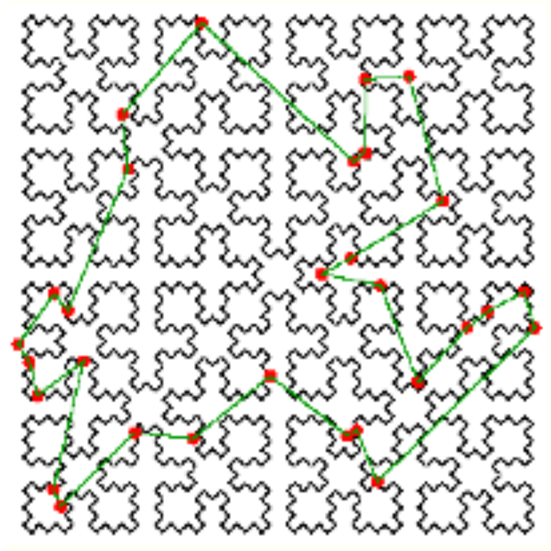
Space filling curve

A curve that passes every point of a square



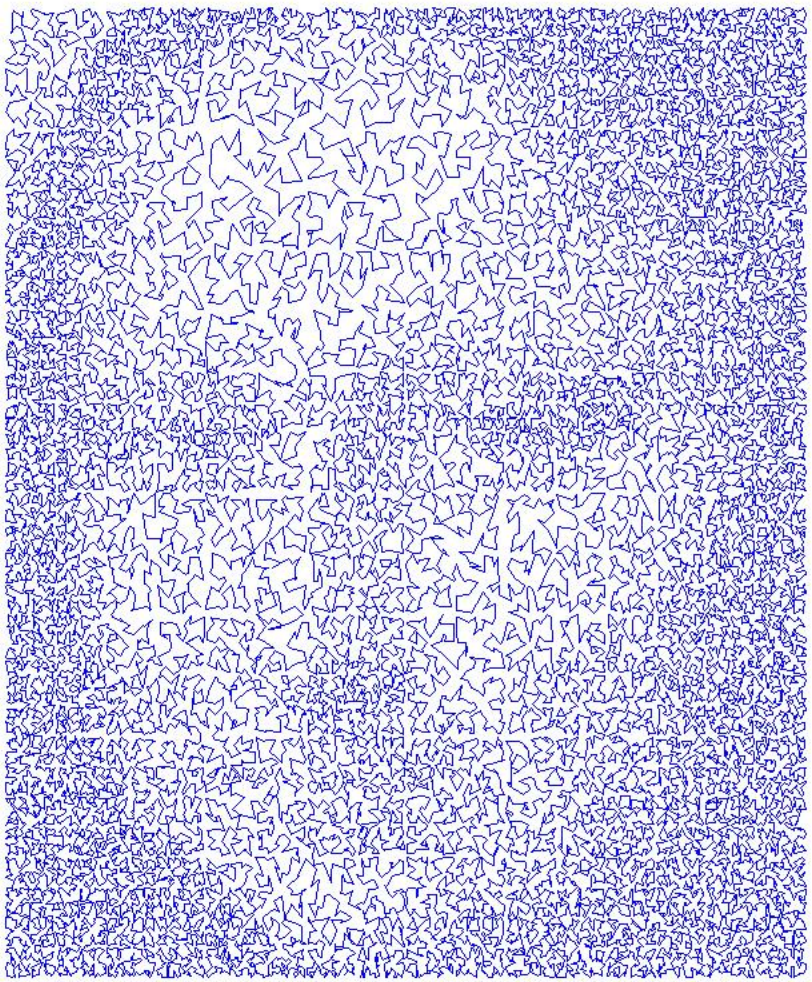
Sierpinski curve

Finding a tour



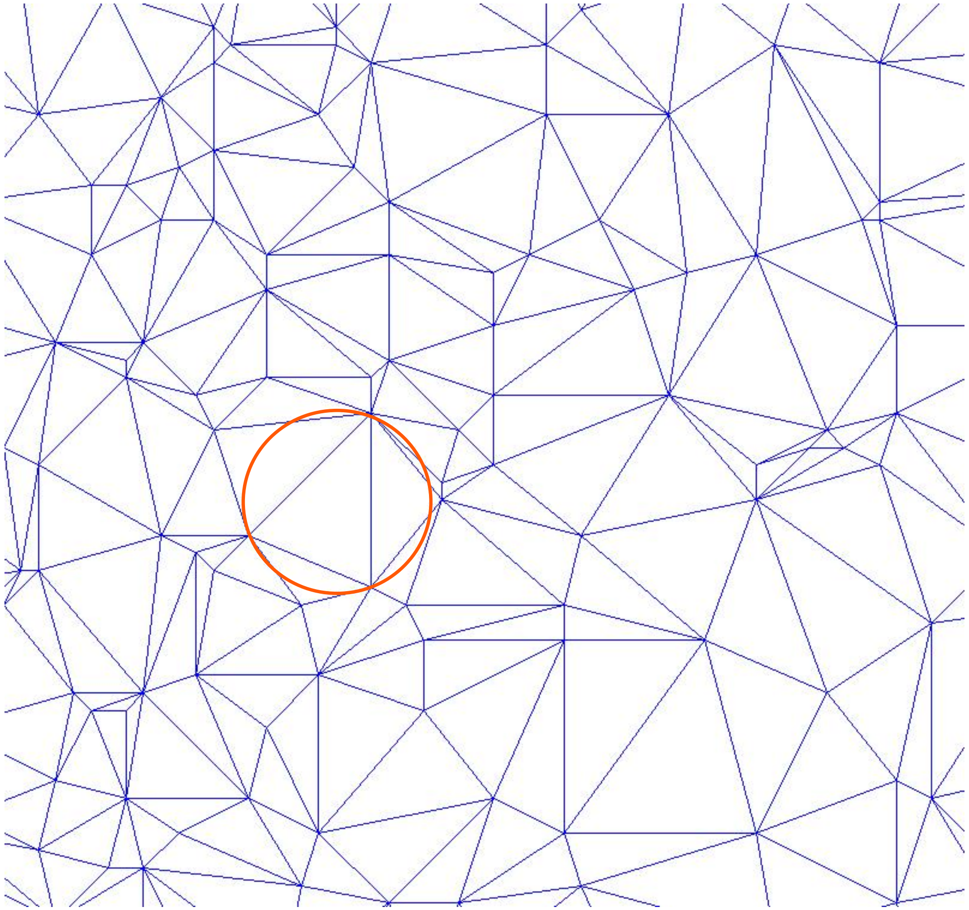
Visit the points in the same order as they appear on the curve

Sierpinski - Mona Lisa



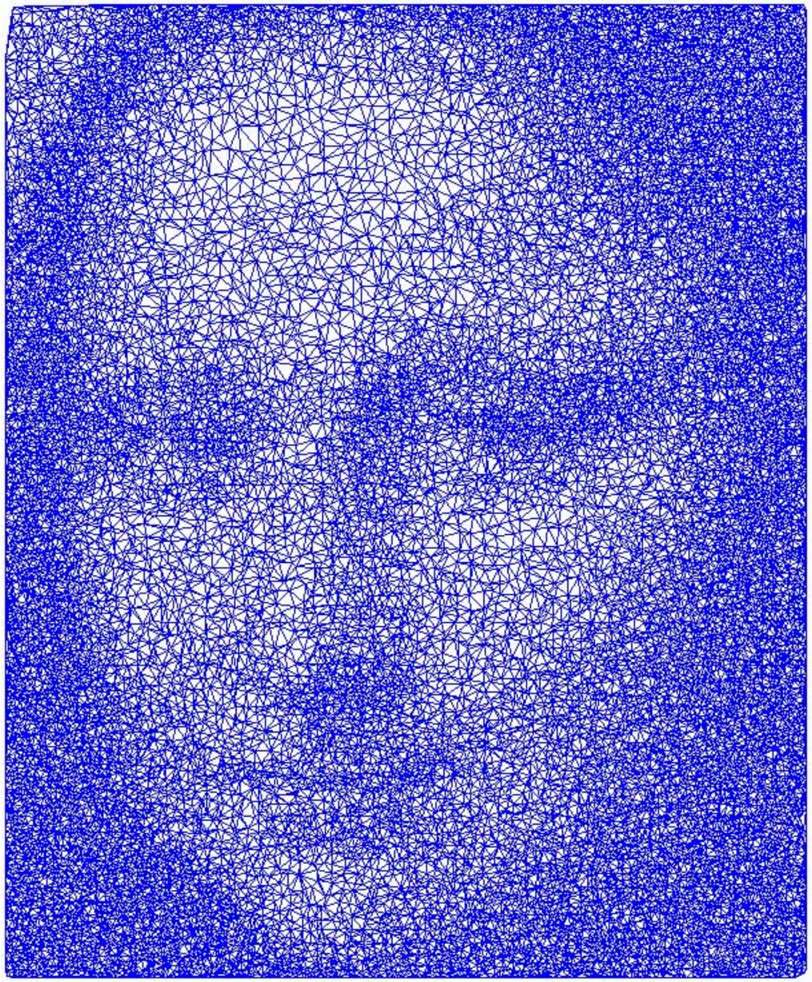
$O(n \log n)$ time

Delaunay triangulation

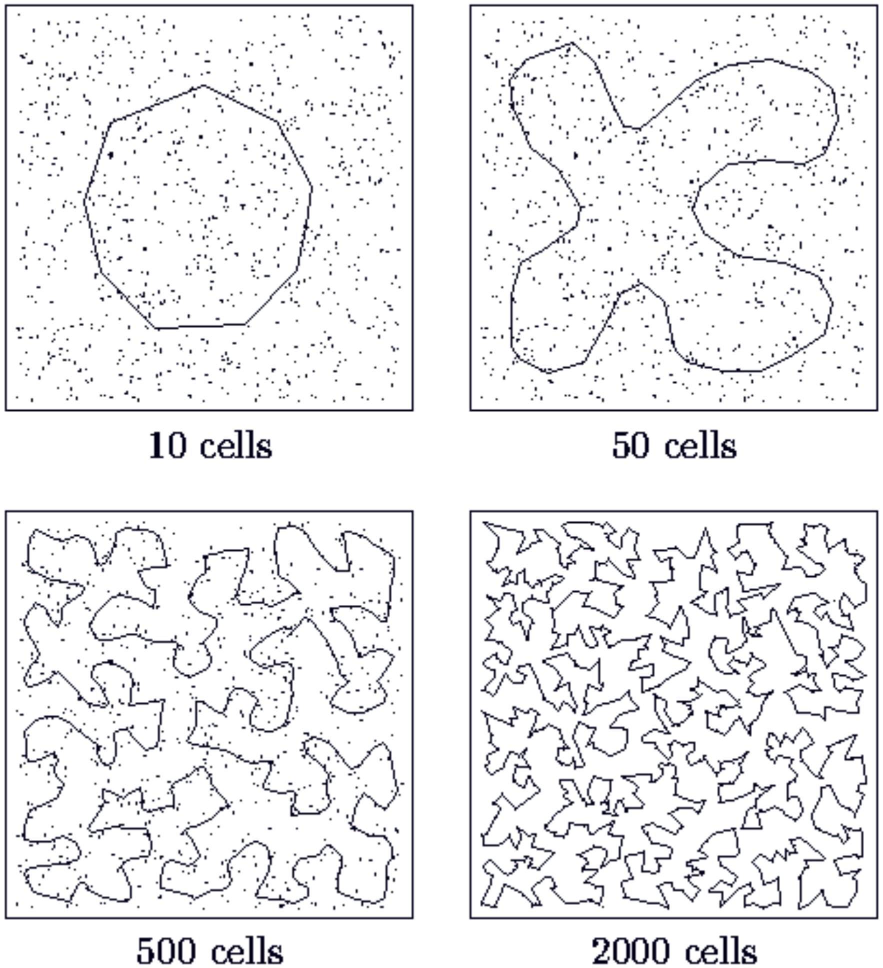


For each triangle, the circumcircle does not contain any other points of the pointset

Triangulized Mona Lisa



Self-organizing neural networks



$O(n)$ time

FlexMap

Additional inspiration

See my web page:

www.ruc.dk/~keld

- Ten proposals in artificial intelligence
- Twelve mixed proposals (in Danish)

See also the project proposals of the members of the PLIS research group:

plis.ruc.dk

Project examples

Look at the library's web site:

http://www.rub.ruc.dk

1980-2004. Unfortunately, without abstracts.

Contact

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