Project Ideas in Computer Science

Keld Helsgaun

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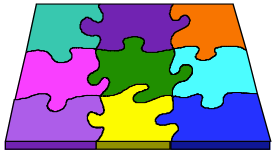


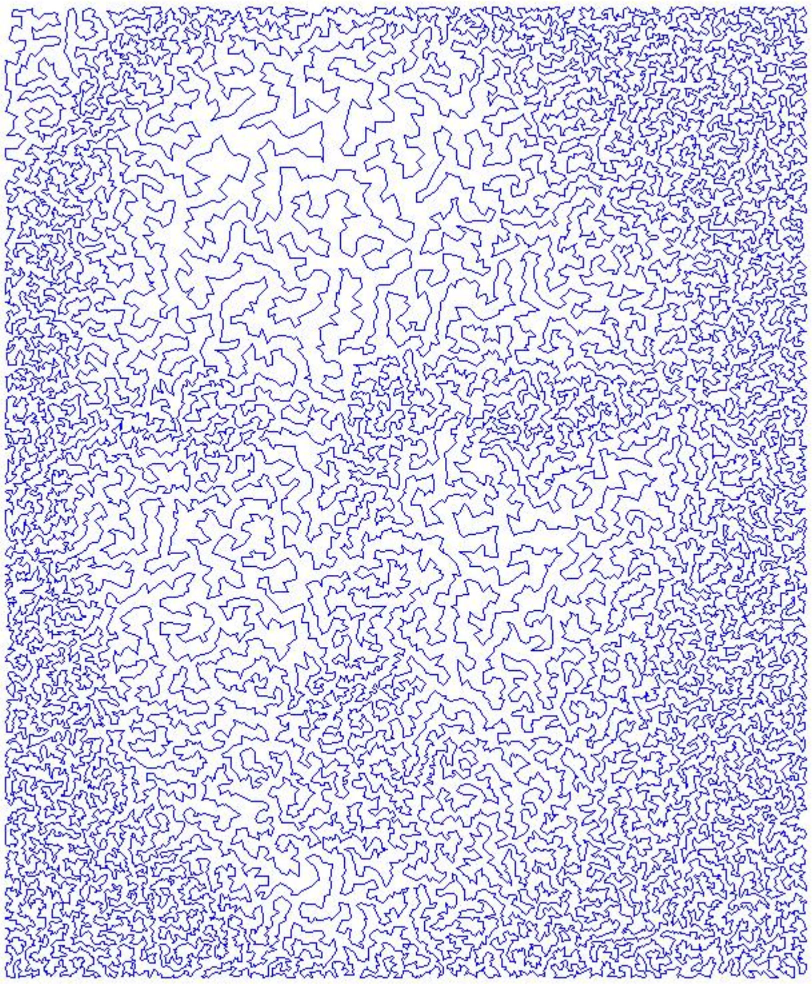
Research:

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

Teaching:

- Programming, algorithms and data structures

OPT-art

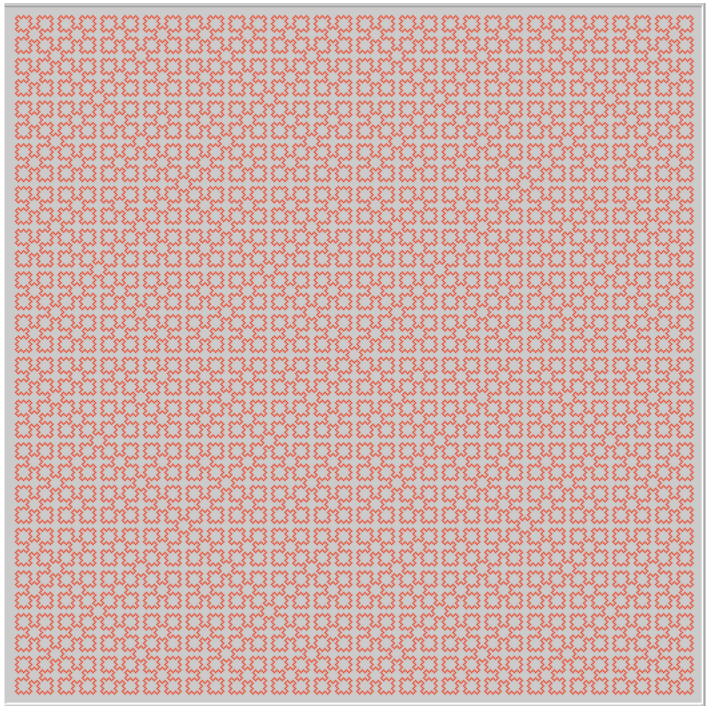


27486 points

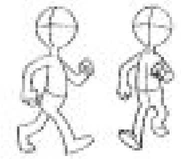
One out of 10^{110079} possible tours

Space filling curve

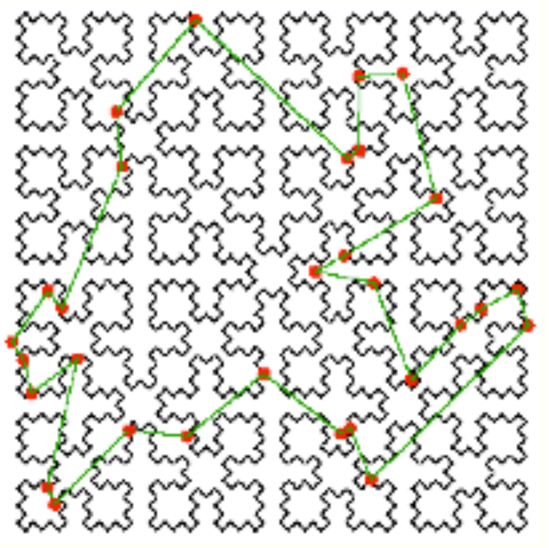
A curve that passes every point of a square



Sierpinski curve

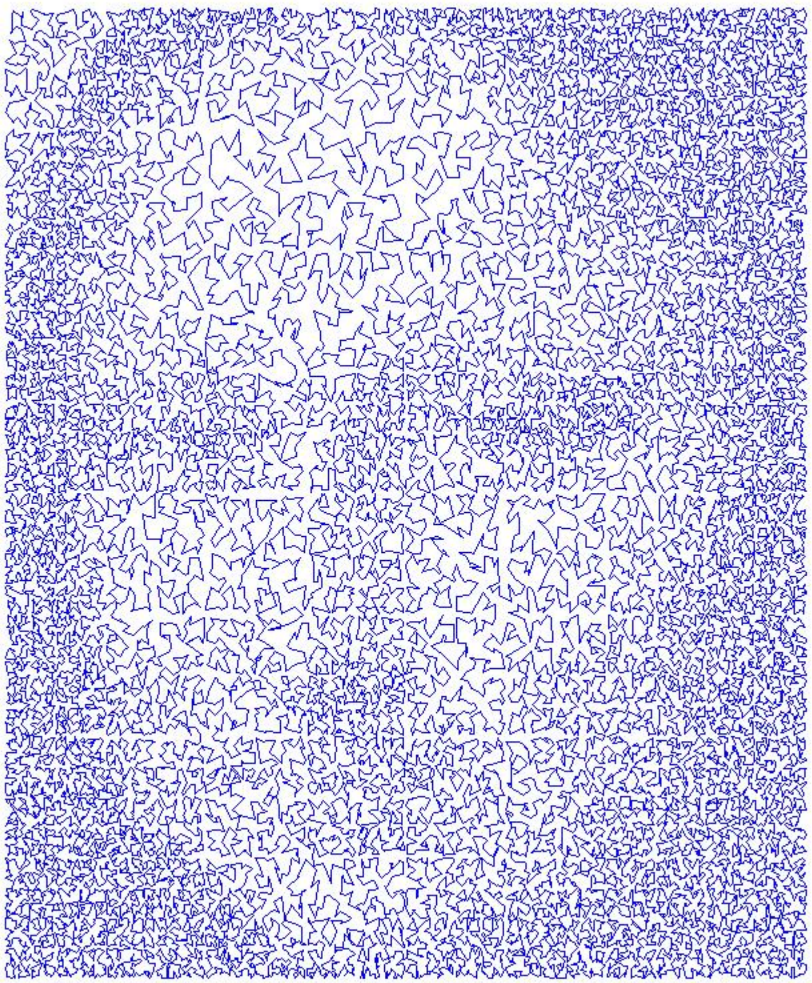


Finding a tour



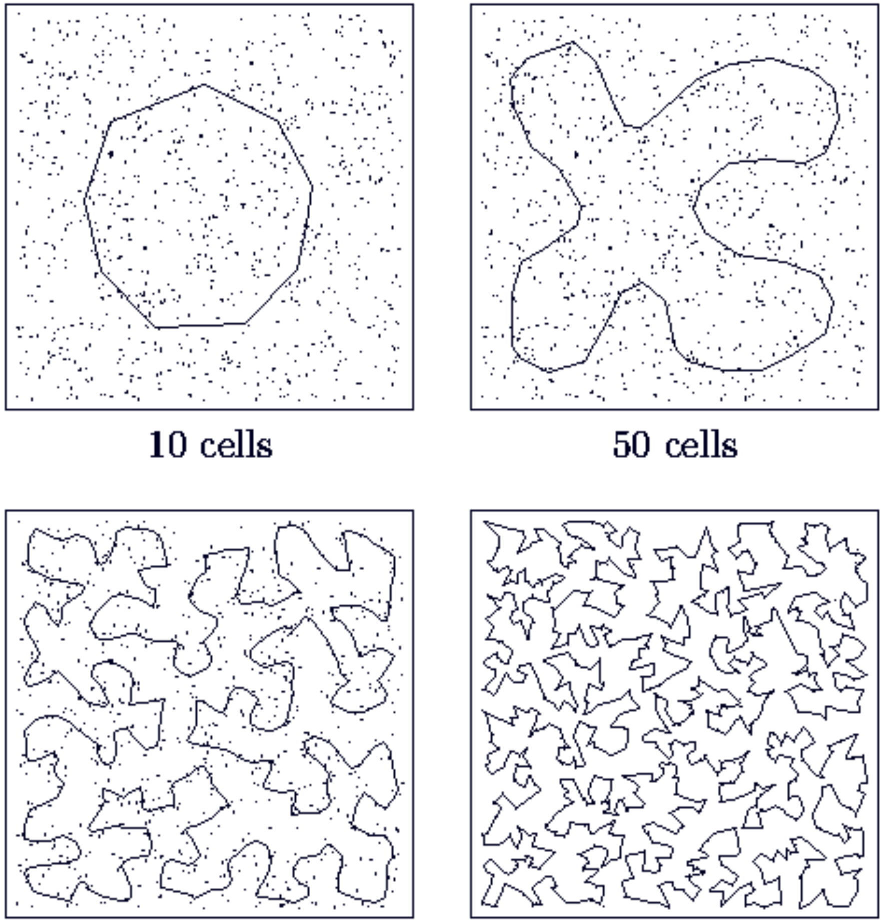
Visit the points in the same order as they appear on the curve

Sierpinski - Mona Lisa



$O(n \log n)$ time

Self-organizing neural networks



10 cells

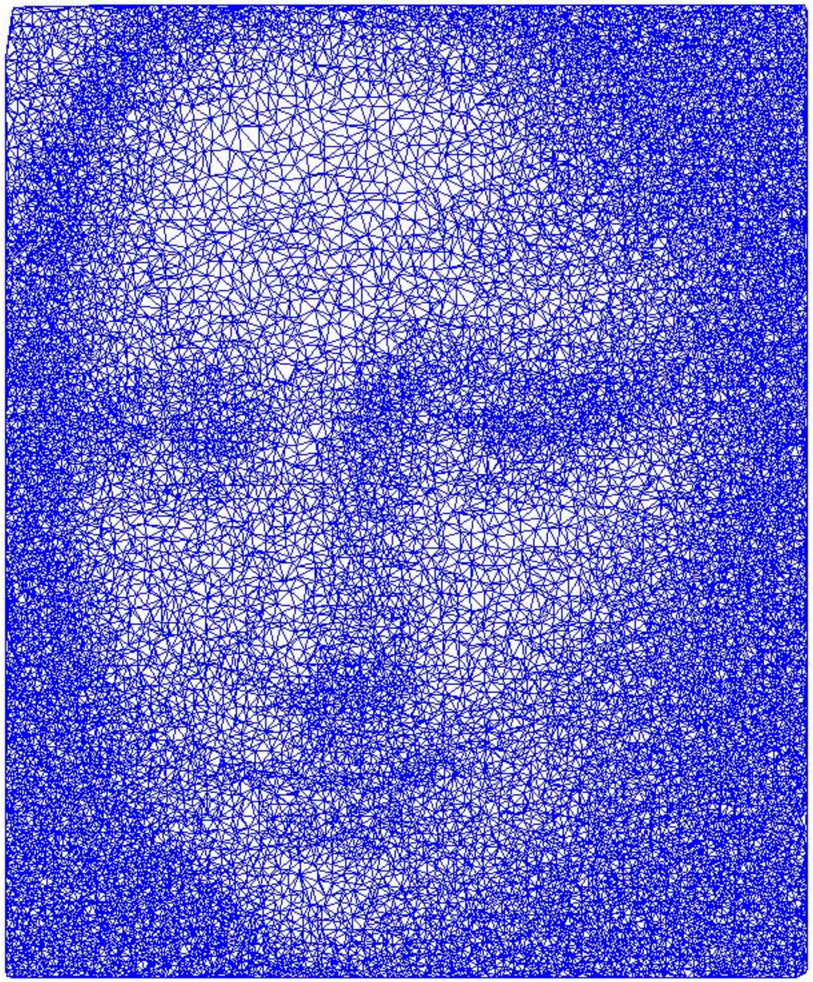
50 cells

500 cells

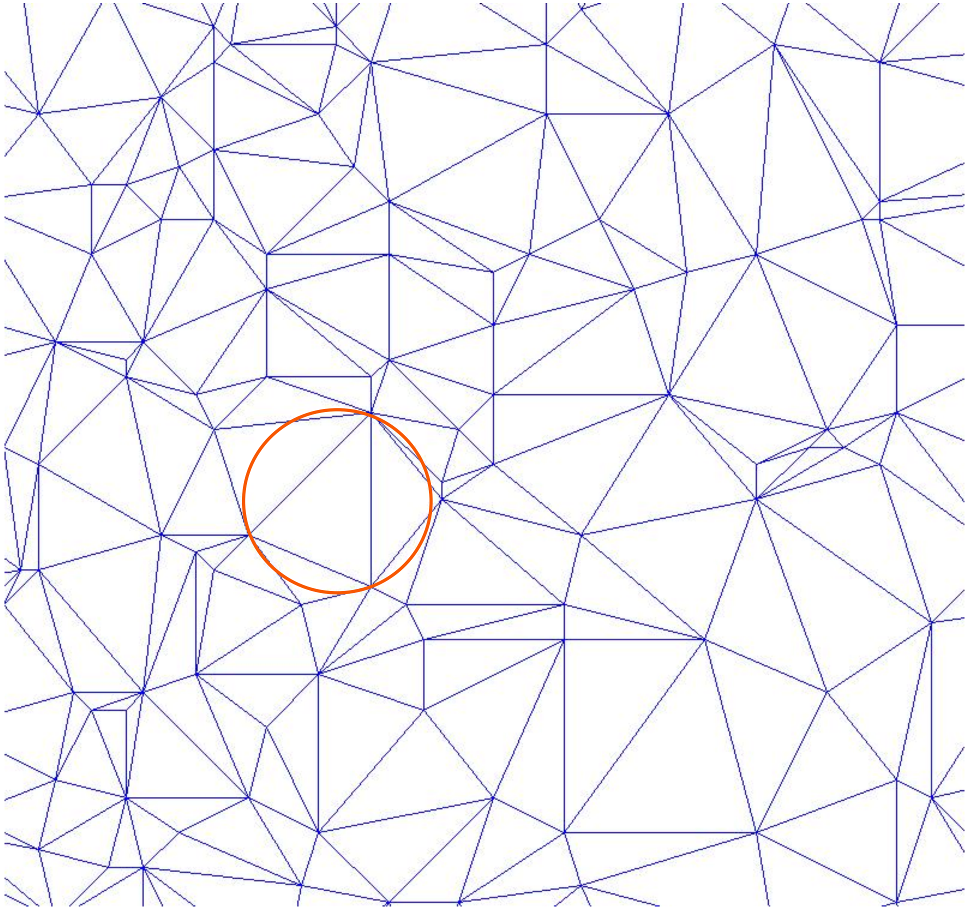
2000 cells

$O(n)$ time

Triangulized Mona Lisa



Delaunay triangulation

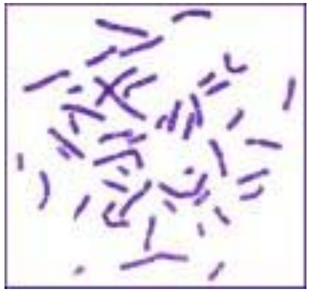


For each triangle, the circumcircle does not contain any other points of the pointset

Genetic algorithms

Darwin’s principle of evolution (“survival of the fittest”) may be used to construct effective optimization algorithms

Genetic algorithms



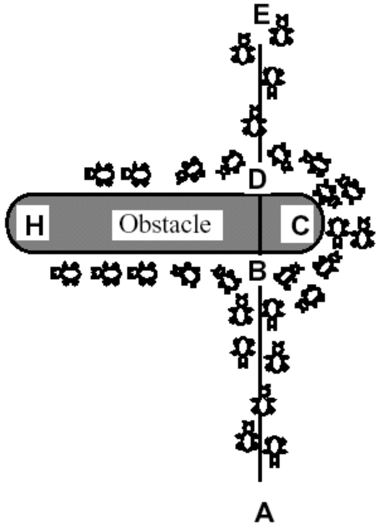
An **individual** (**chromosome**) represents a candidate solution for the problem at hand.

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, respectively.

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.



http://dsp.jpl.nasa.gov/members/payman/swarm/sciam_0300.pdf

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.

Timetabling

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

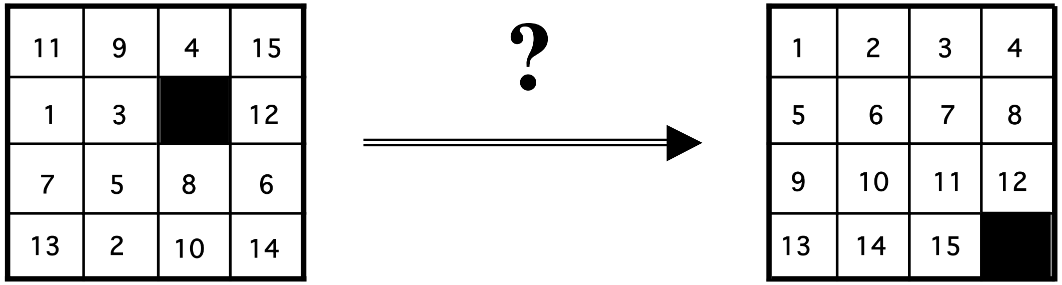
Course planning: Assign each lecture to some period of the week in such a way that no student is required to take more than one lecture at a time.

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

Problem solving

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

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



11	9	4	15
1	3	■	12
7	5	8	6
13	2	10	14

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	■

Rubik’s cube

Automatic theorem proving

- **Theorem proving**: to show that a statement follows logically from some other statements
- **Automatic** theorem proving: a mechanization of the proof

Example

- Given the following 2 statements:

All humans are mortal.
Socrates is a human.

- Show that we may conclude that:

Socrates is mortal.

Project idea

Development of a program that reads a series of logical statements, checks their correctness, and converts them into a form that may be used in an existing program for automatic theorem proving.

Input: Logical statements in first order predicate

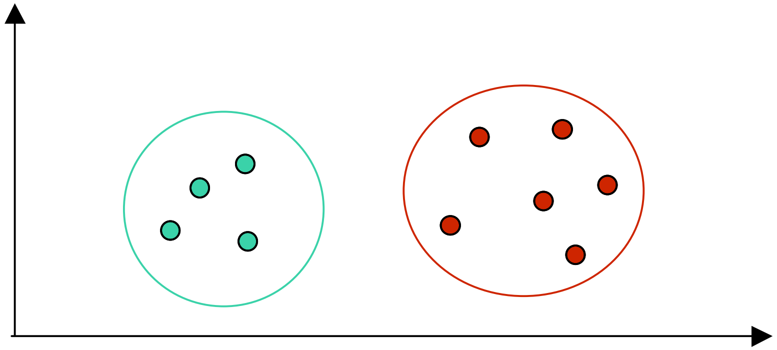
Output: The statements transformed into disjunctive normal form

Subjects: Syntax, semantics and translation

Data mining

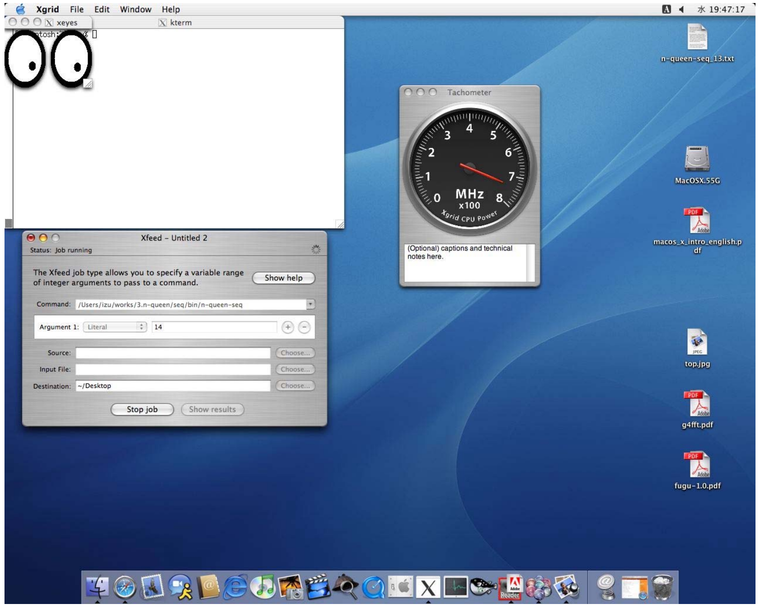
Analysis of large data sets with the purpose of finding meaningful patterns in the data.

Example: **cluster analysis**



Distributed algorithms

Application of **xgrid** for distributed solution of some chosen problem.



(Optional) captions and technical notes here.

Status: Job running

The Xfeed job type allows you to specify a variable range of integer arguments to pass to a command.

Command: /Users/izu/works/3.n-queen/seq/bin/n-queen-seq

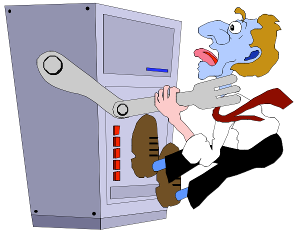
Argument 1: Literal 14

Source:

Input File:

Destination: ~/Desktop

Simulation of a computer



Development of a simulator for Donald Knuth's MMIX machine.

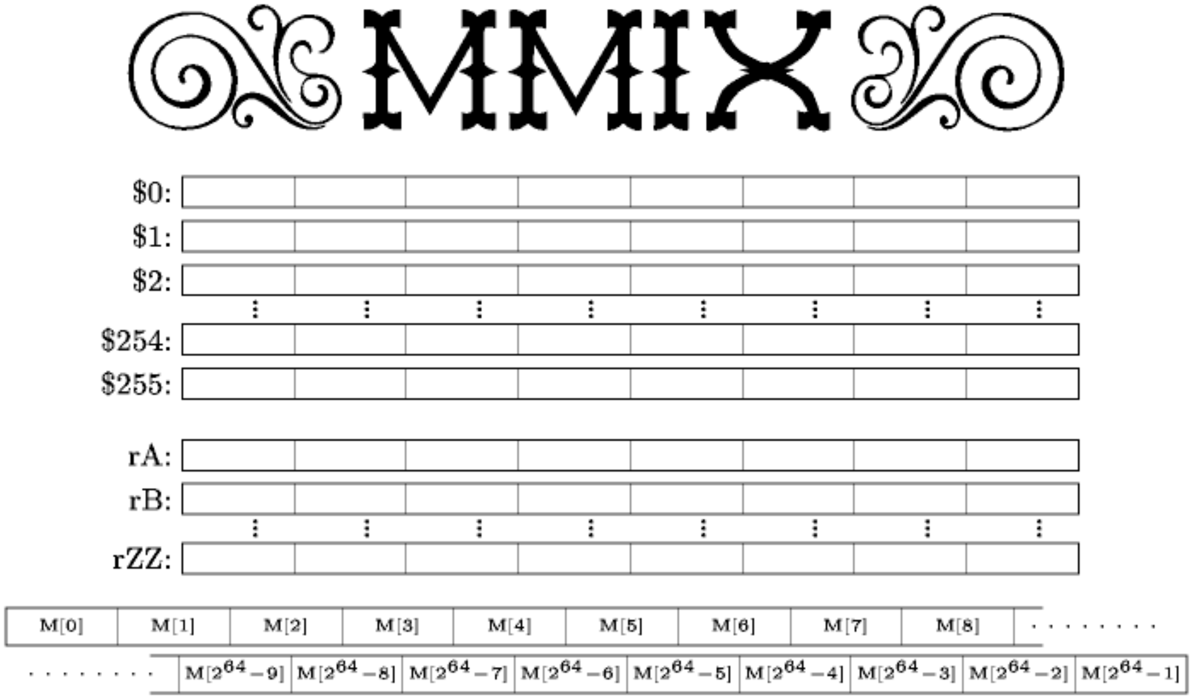
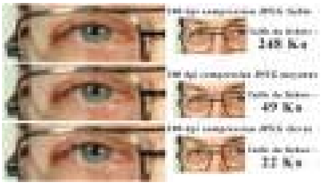
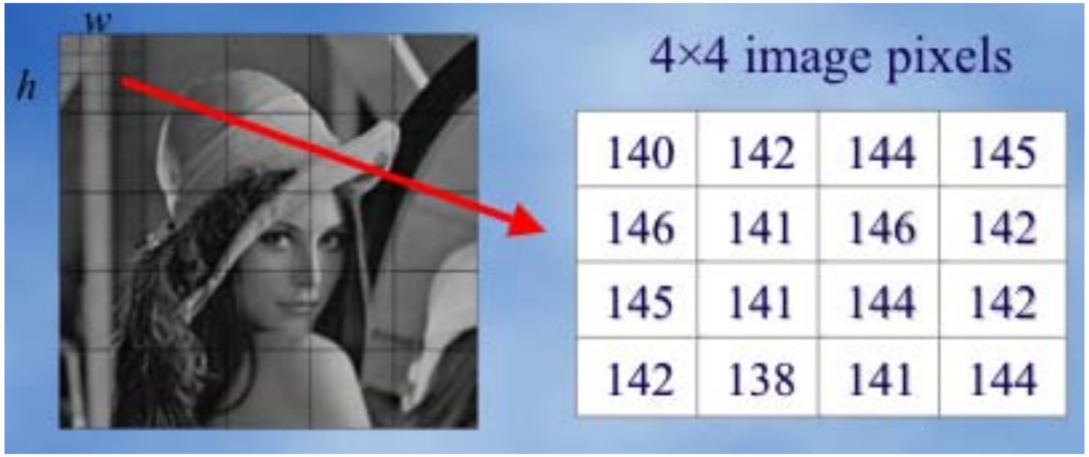


Image compression



Compression of images be means of block truncation.



4×4 image pixels

140	142	144	145
146	141	146	142
145	141	144	142
142	138	141	144

Symbolic differentiation

Given a symbolic expression as the following:

$\sin^2(3x-2) + (3-2x)/(3+2x)$

Input the expression. Output the differential quotient with respect to x:

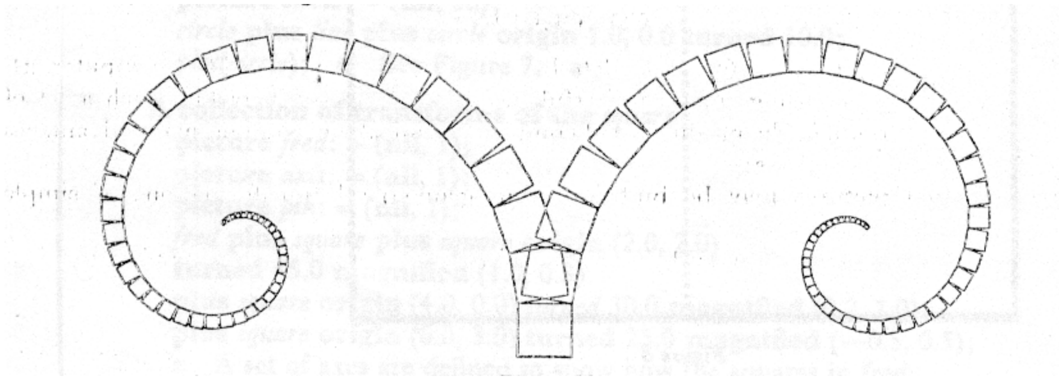
$-3/2(\cos(6x-9) - \cos(2x-3)) - 12/(3+2x)^2$

Representation of images

Development of a program that, given a description as this one:

```
Picture spiral = new Picture(50);
spiral.plus(square).plus(spiral.origon(0,1).turned(10).
                    magnified(0.95, 0.95));
Picture ram = new Picture(1);
ram.plus(spiral).plus(spiral.origon(1,0).magnified(-1,1));
```

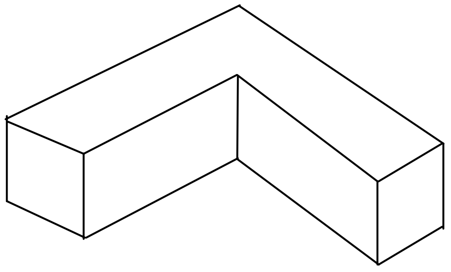
draws the picture



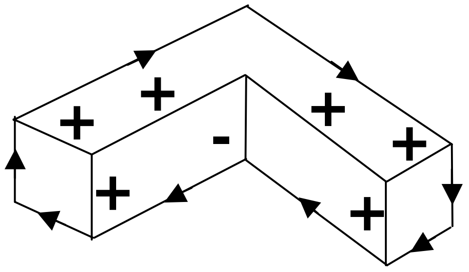
Wyvill, B.L.M. PICTURES-68 MK1. Software --- Practice and Experience, 7 (1977), pp 251--261.

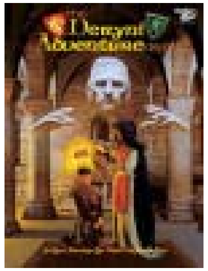
Computer vision

Given a figure as the one shown below:



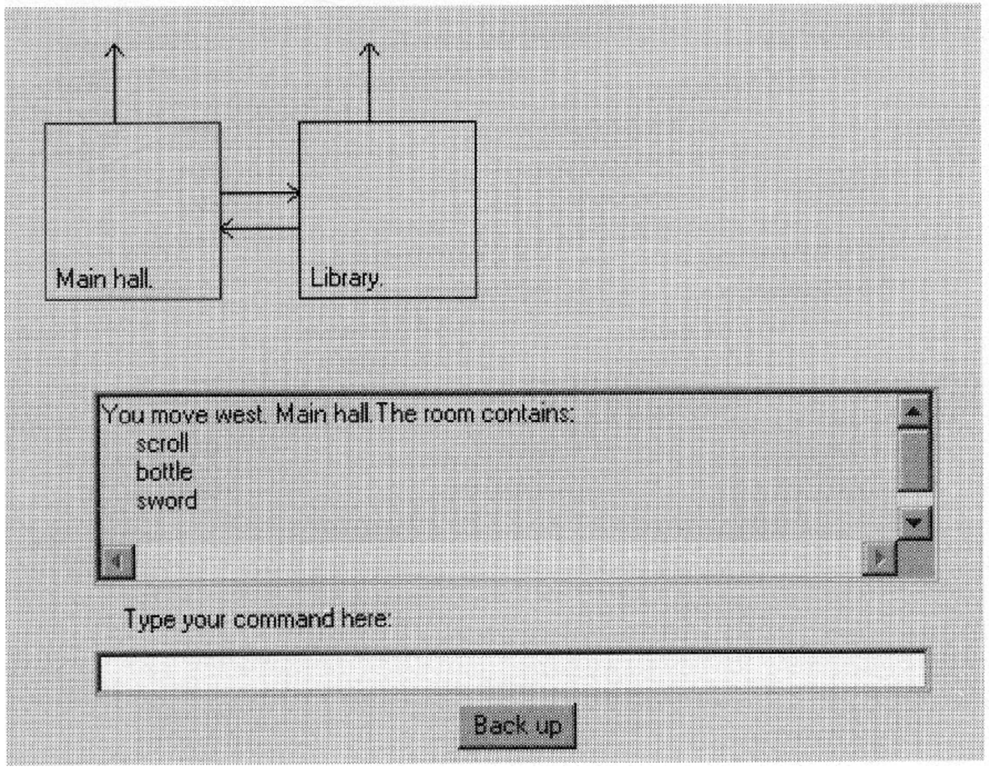
Determine which edges that make up the outline of the figure (→), and which inner edges that are oriented towards (+) or away (-) from the viewer.





Adventure games

Development of an adventure game program in Java.

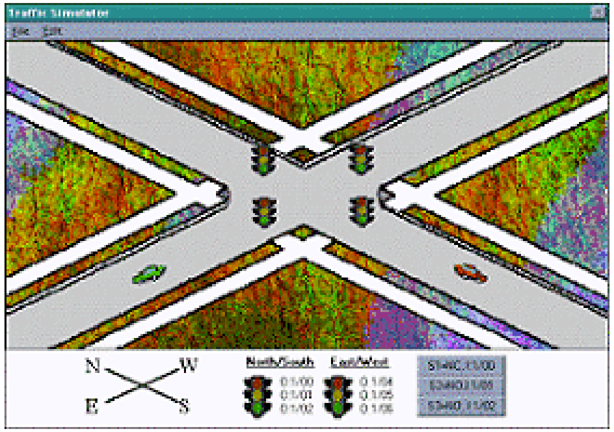


```
You move west. Main hall.The room contains:
    scroll
    bottle
    sword
```

Optimization of simulation models

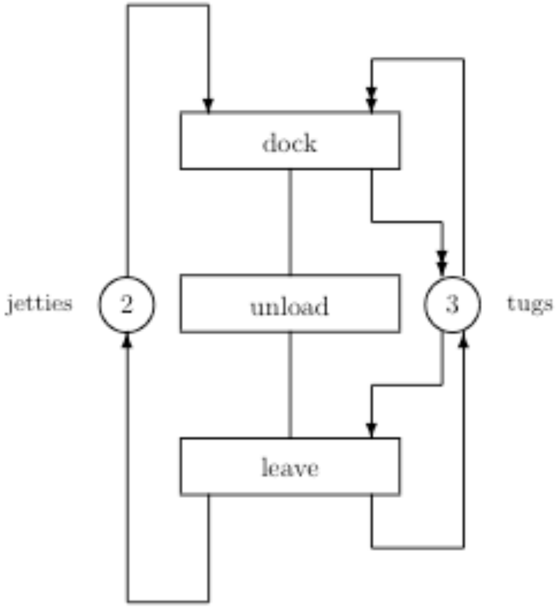
Development of a general tool for optimization in connection with simulation.

Example: Optimization of traffic lights.

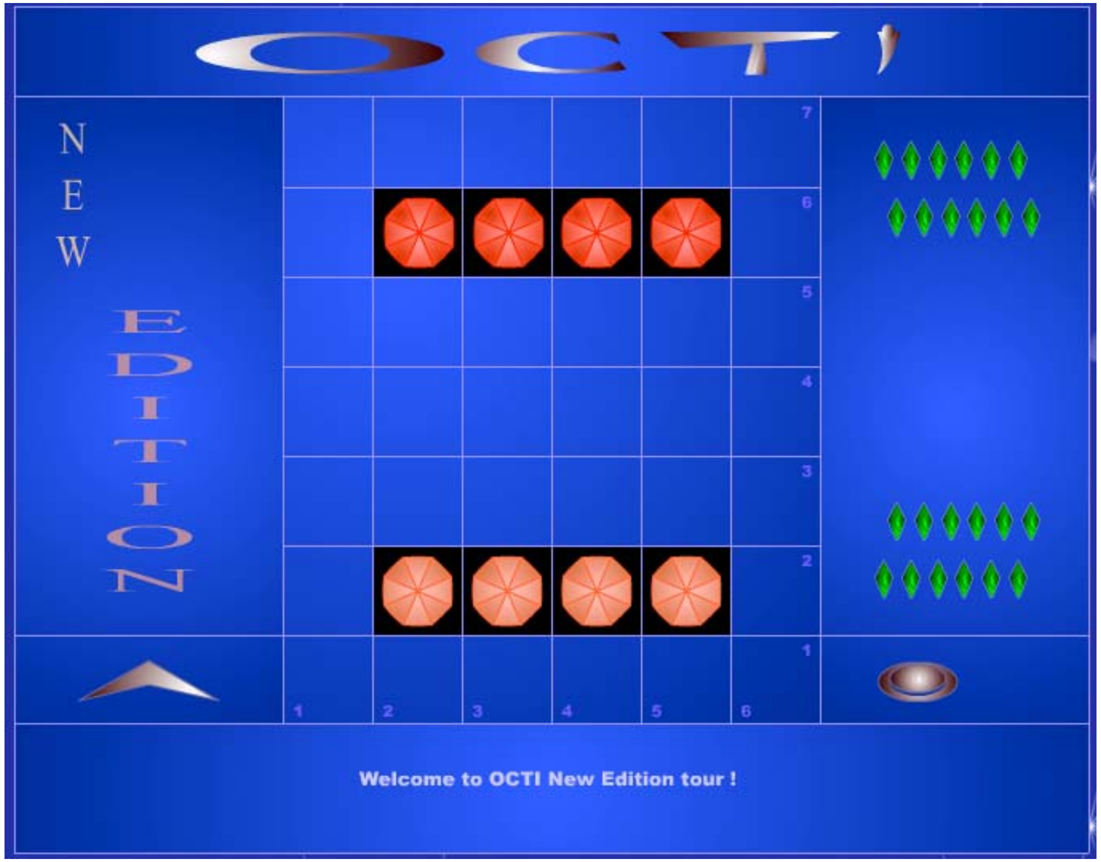


The simulation language DEMOS

A Java implementation of DEMOS (Discrete Event Modelling on Simula).



The game OCTI



Welcome to OCTI New Edition tour !

Don Green (2002)

Bioinformatics

Involves:

- Modeling of biological processes
- Formulation of computational problems
- Design ans analysis of algorithms
- Development and use of programs

Focus on genetic sequence analysis.
Example: How similar are two gene sequences?

Sorting by reversals

Given a permutation og the integers 1 to *n*.
Determine the shortest sequence of reversals that transforms the permutation into (1 2 3 ... *n*).

Example:

$4\ 3\ 2\ \underline{8\ 7\ 1}\ 5\ 6$

$\underline{4\ 3\ 2\ 1}\ 7\ 8\ 5\ 6$

$1\ 2\ 3\ 4\ \underline{7\ 8}\ 5\ 6$

$1\ 2\ 3\ 4\ 8\ 7\ \underline{5\ 6}$

$1\ 2\ 3\ 4\ \underline{8\ 7\ 6\ 5}$

$1\ 2\ 3\ 4\ 5\ 6\ 7\ 8$ 5 reversersals

Additional inspiration

See the web page:

www.akira.ruc.dk/~keld/teaching/Projektforslag

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

Contact

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