Vision

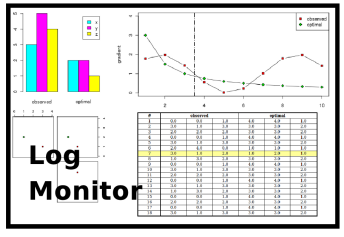
Optimization under uncertainty toolkit:

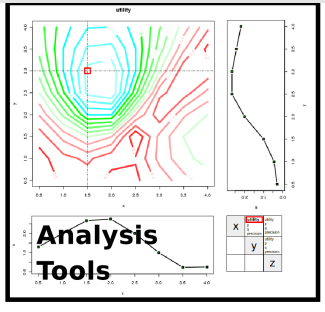
- test bench for development of new algorithms;
- reference implementation of the algorithms;
- library of limited-rationality-based optimization algorithms for use in real-world applications.

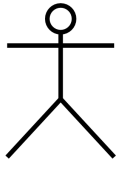
Roles

- **AI Scientist:** develops core optimization algorithms for the toolkit;
- **Researcher:** a colleague of the AI scientist, uses the toolkit as a part of an experiment;
- **Application Engineer:** employs the algorithms as black boxes, components in an industrial environment.

Author's Viewpoint







Algorithm
Author

Problem
definitions

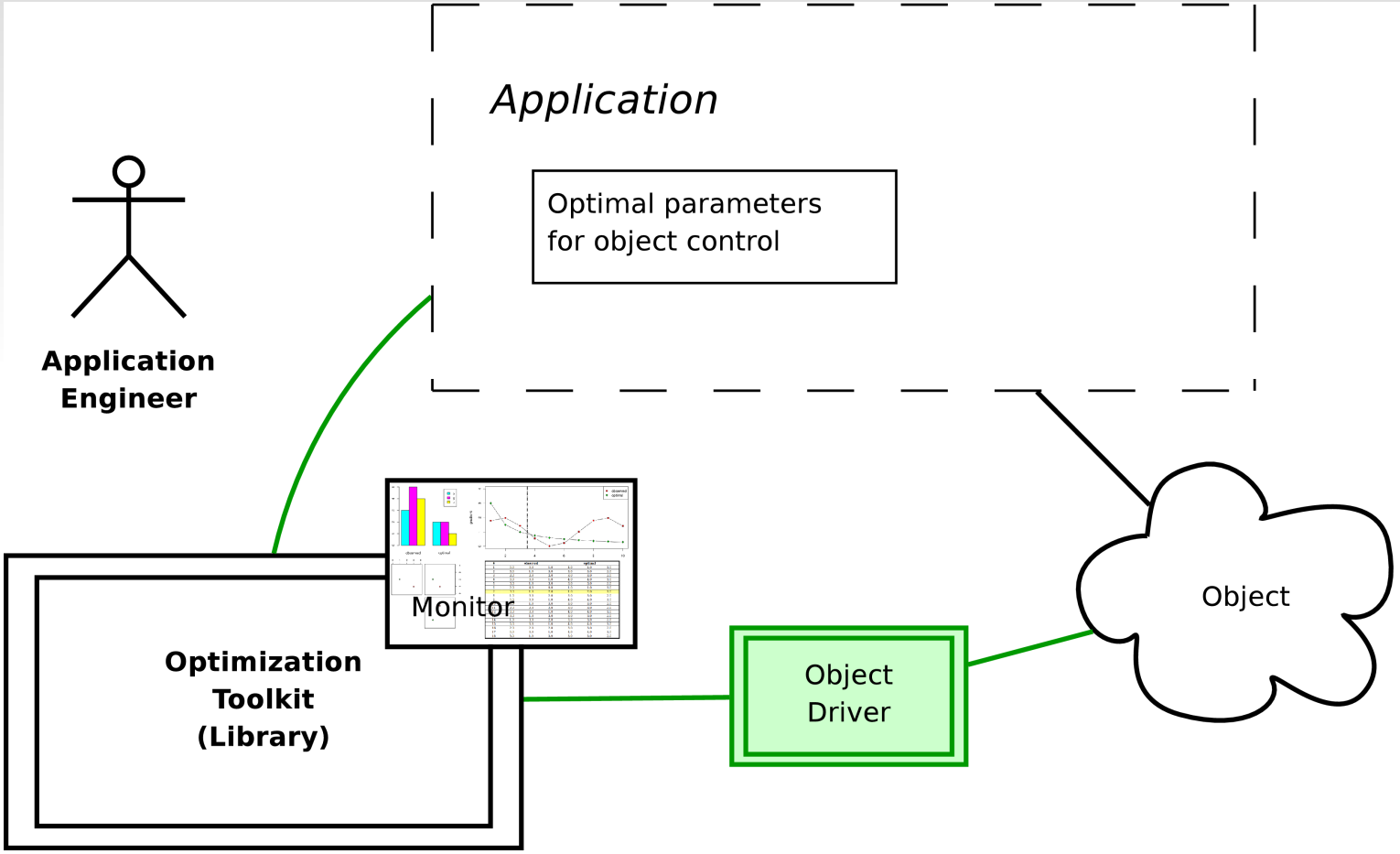
Simulation
Data

Solver

Model
Library

Algorithm
Library

User's Viewpoint

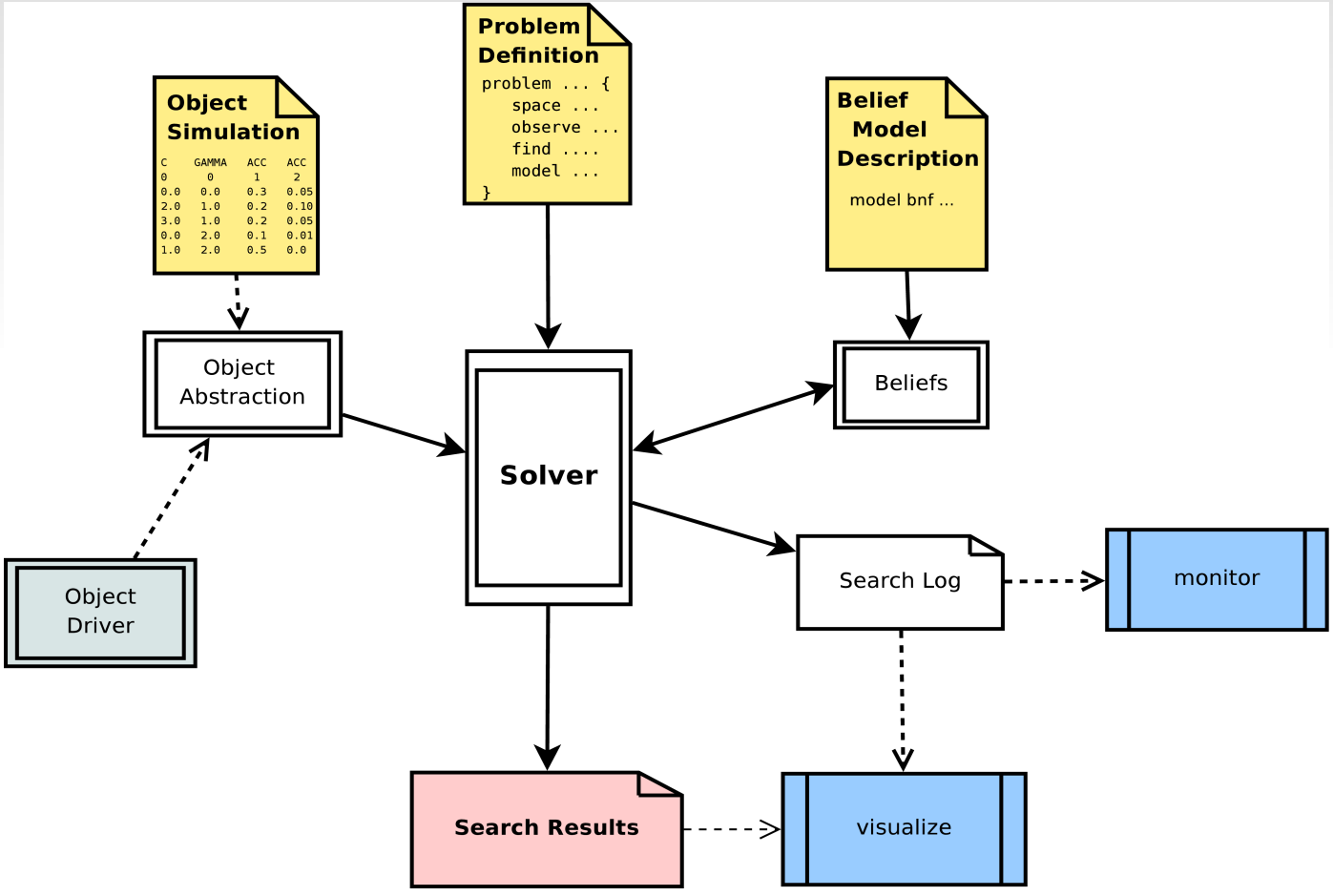


Tool Approach

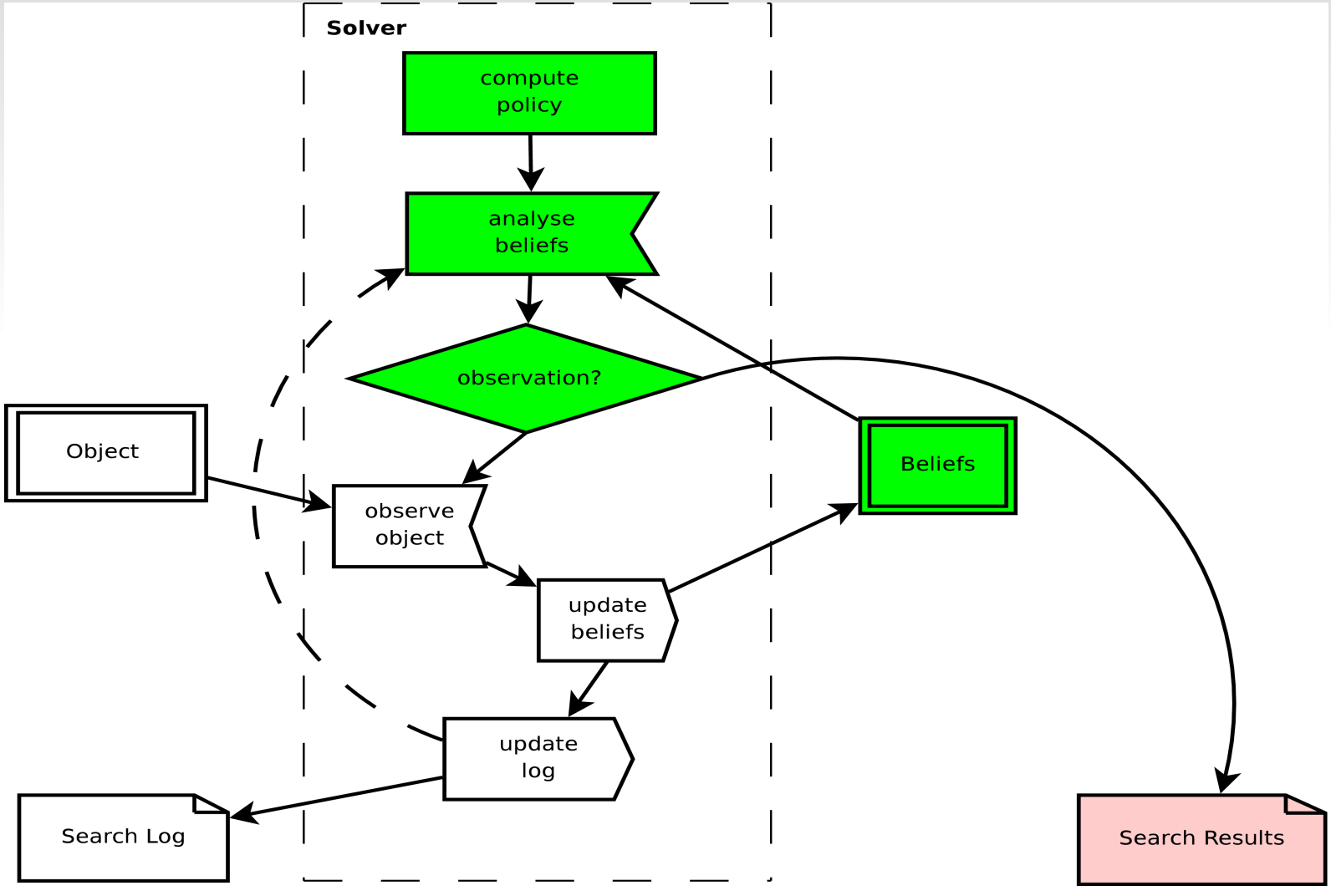
Set of self-contained tools:

- easy to implement;
- supports exploratory development of search solutions;
- provides flexible tools for experiments and data analysis;
- allows easy packaging of the algorithms for industrial use.

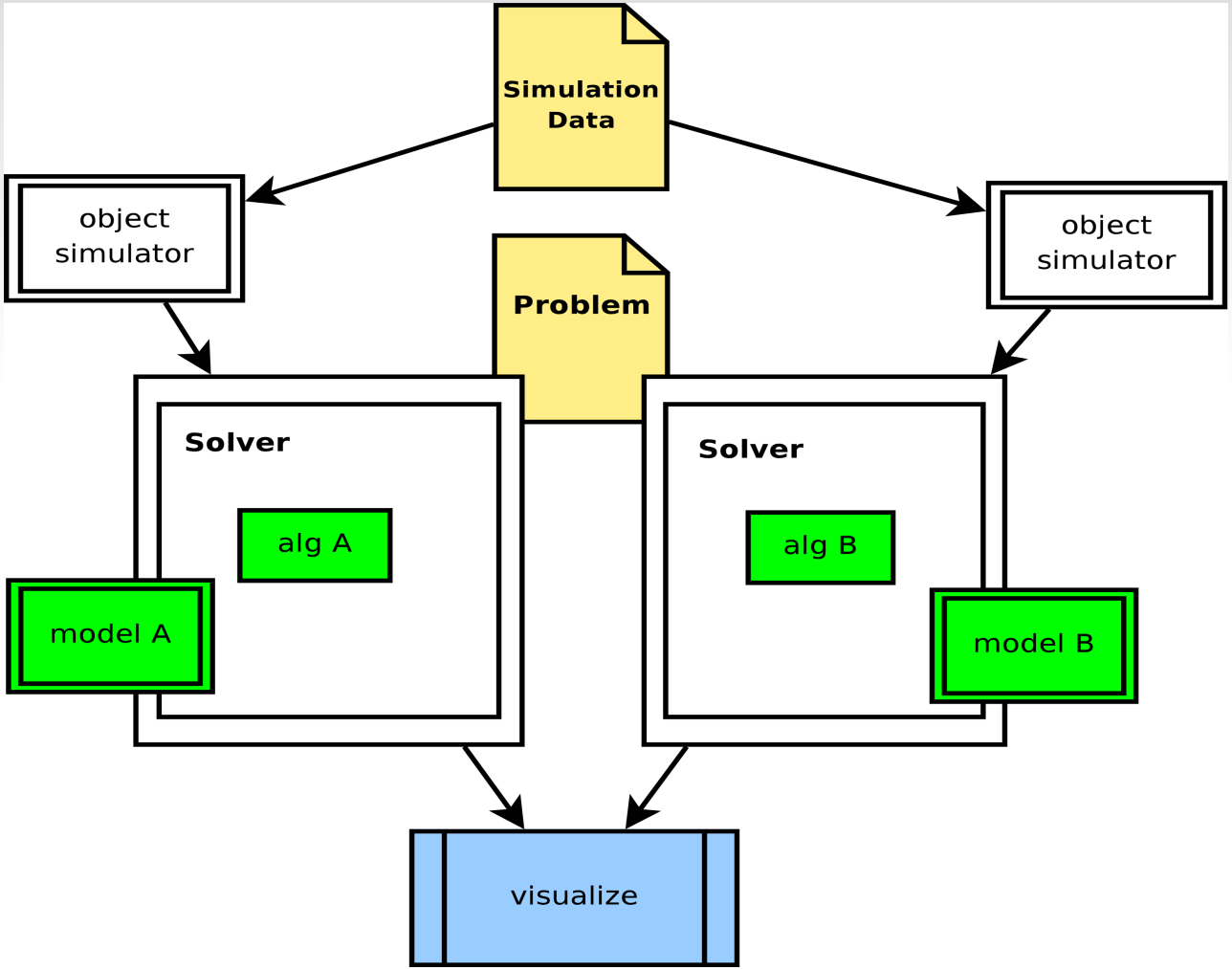
Solver — Environment



Solver — Algorithm

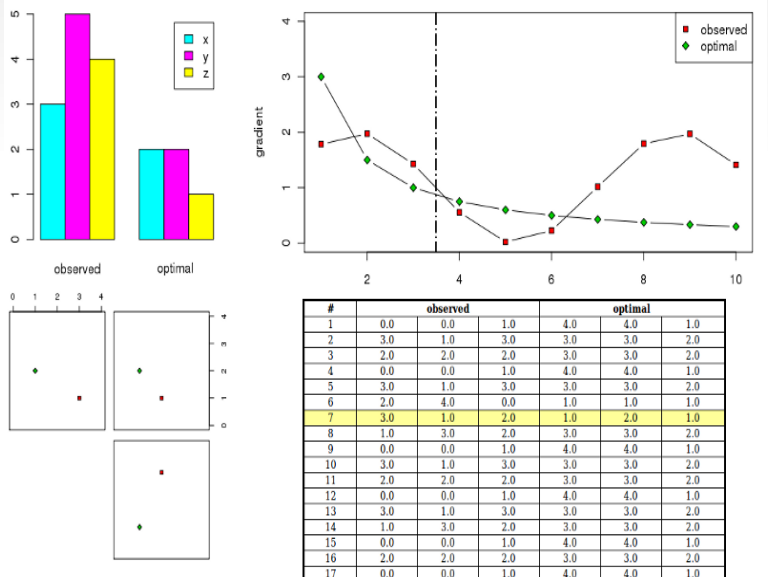


Pairwise Comparison



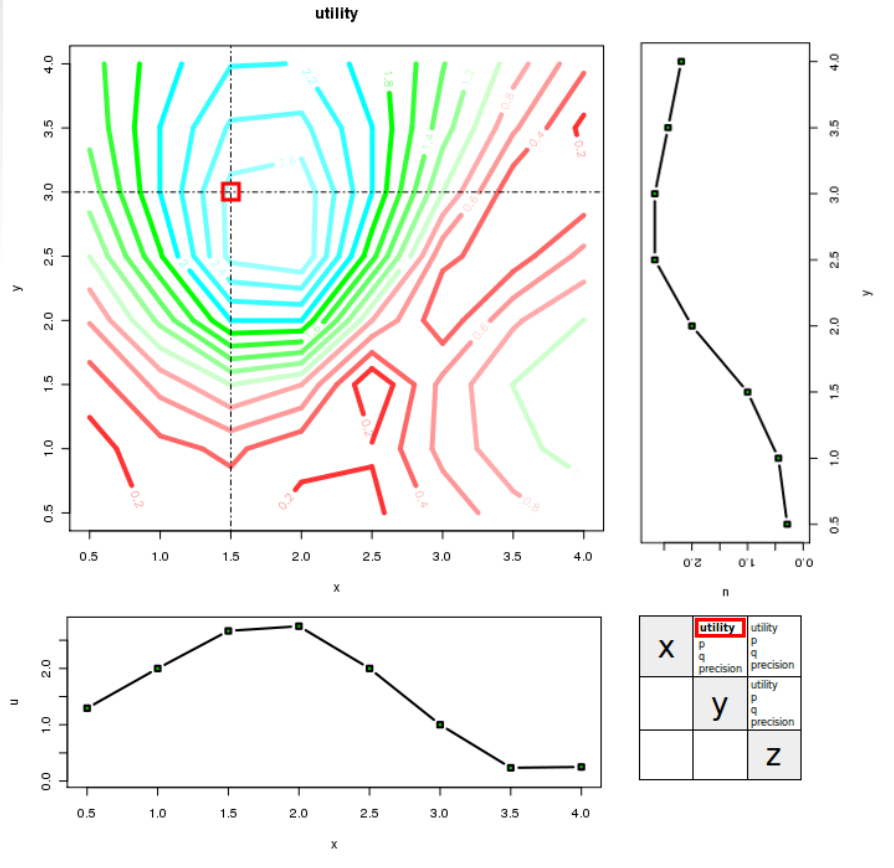
GUI Tools

Monitoring



#	observed			optimal		
1	0.0	0.0	1.0	4.0	4.0	1.0
2	3.0	1.0	3.0	3.0	3.0	2.0
3	2.0	2.0	2.0	3.0	3.0	2.0
4	0.0	0.0	1.0	4.0	4.0	1.0
5	3.0	1.0	3.0	3.0	3.0	2.0
6	2.0	4.0	0.0	1.0	1.0	1.0
7	3.0	1.0	2.0	1.0	2.0	1.0
8	1.0	3.0	2.0	3.0	3.0	2.0
9	0.0	0.0	1.0	4.0	4.0	1.0
10	3.0	1.0	3.0	3.0	3.0	2.0
11	2.0	2.0	2.0	3.0	3.0	2.0
12	0.0	0.0	1.0	4.0	4.0	1.0
13	3.0	1.0	3.0	3.0	3.0	2.0
14	1.0	3.0	2.0	3.0	3.0	2.0
15	0.0	0.0	1.0	4.0	4.0	1.0
16	2.0	2.0	2.0	3.0	3.0	2.0
17	0.0	0.0	1.0	4.0	4.0	1.0
18	3.0	1.0	3.0	3.0	3.0	2.0

Results Analysis



Problem — SVM RBF

```
problem svm {

  space (C, gamma) {
    C = [-8, -6 .. 8] / 0.0;
    gamma = [ -12, -9 .. 12 ] / 0.0;
  }

  observe acc {
    1=> acc = 0.5  / 0.10;
  }

  find max util[C,gamma] = acc;

  model grid(C, gamma) {
    acc = (0.0, 100.0) / (2.0, 2.0) ;
  }

}
```

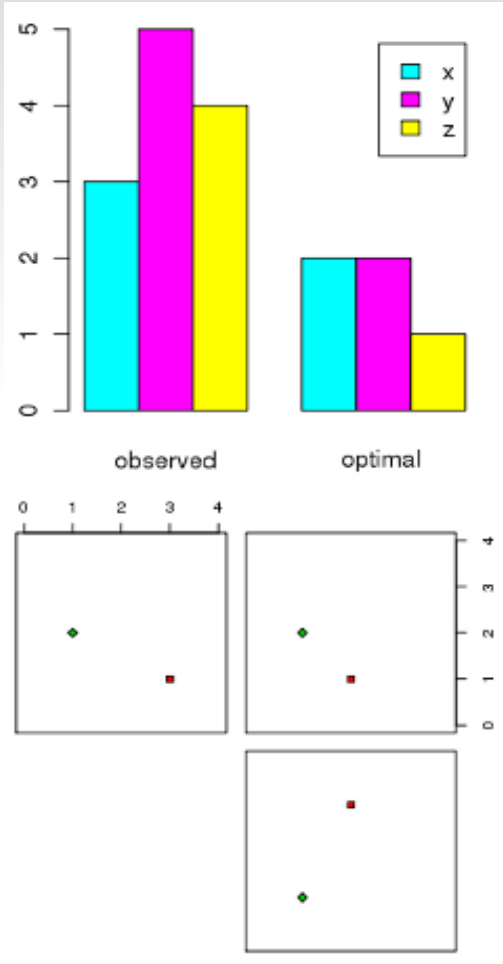
- Find best C, γ for SVM RBF
- Maximize classification accuracy
- Use uniform 2-dimensional grid dependency model

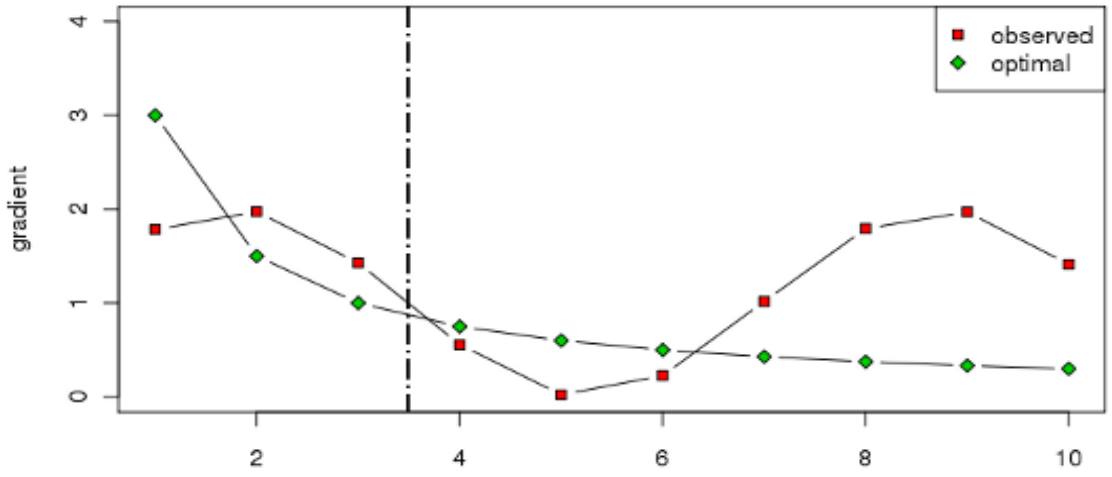
Problem — Wafer Setup

```
problem wafer {

  space (site, focus, color, angle) {
    site = [1, 2 .. 5] / 60;
    focus = [1, 2 .. 31 ] / 60;
    color = [1, 2 .. 5 ] / 60;
    angle = [0, 180] / 300;
  }

  observe (x, y, px, py) {
    1 => (x, y, px, py) = (1.0, 1.0, 100.0, 100.0) / 30;
  }

  find max merit[focus, color] =
        1/2-1/12*(tanh((xprec-a_prec)/c_prec)
               +tanh((yprec-a_prec)/c_prec)
              +tanh((xtis-a_tis)/c_tis)
               +tanh((ytis-a_tis)/c_tis)
                +tanh((xtsv-a_tsv)/c_tsv)
               +tanh((ytsv-a_tsv)/c_tsv)) {
       xprec = mean(px);
       yprec = mean(py);
       xtis = mean(x[angle=1]-x[angle=0]);
       ytis = mean(y[angle=1]-y[angle=0]);
       xtsv = sd(x[angle=1]-x[angle=0]);
       ytsv = sd(y[angle=1]-y[angle=0]);
       a_prec = 1.0;
       c_prec = 1.0;
       a_tis = 1.0;
       c_tis = 1.0;
       a_tsv = 1.0;
       c_tsv = 1.0;
  }

  model bif “wafer.bif”;
}
```

- Find best focus and color for wafer measurement
- Observe four features (x, y, px, py) in 4-dimensional space (site, focus, color, angle)
- Maximize utility function of 6 arguments
- Use dependency model in Bayes Interchange Format, stored in external file

Monitoring





#	observed			optimal		
1	0.0	0.0	1.0	4.0	4.0	1.0
2	3.0	1.0	3.0	3.0	3.0	2.0
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4	0.0	0.0	1.0	4.0	4.0	1.0
5	3.0	1.0	3.0	3.0	3.0	2.0
6	2.0	4.0	0.0	1.0	1.0	1.0
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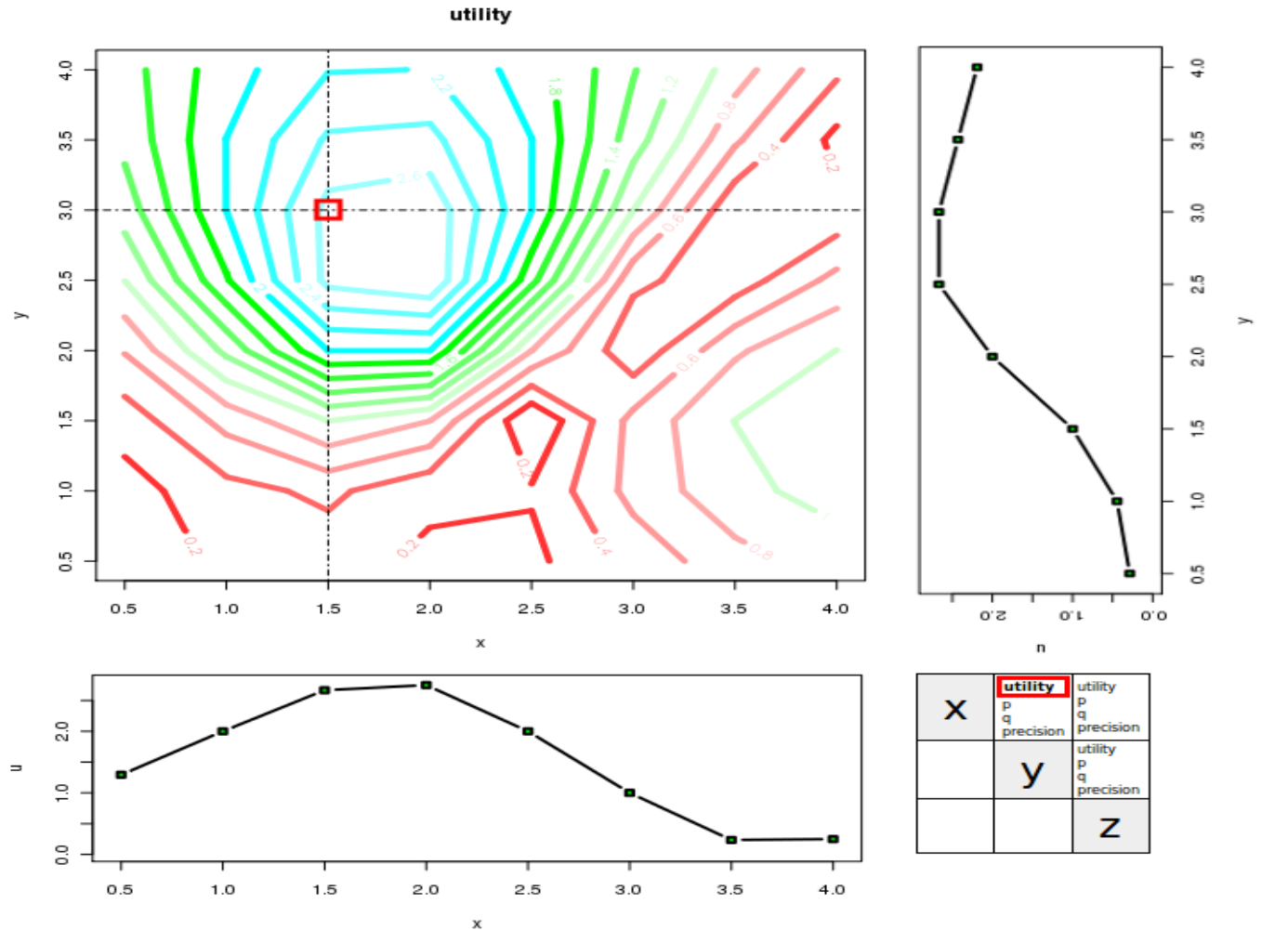
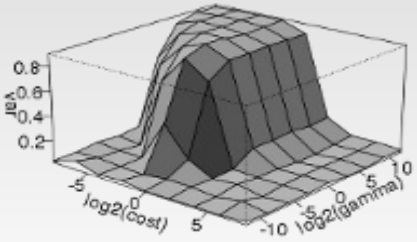
18	3.0	1.0	3.0	3.0	3.0	2.0

Results Analysis



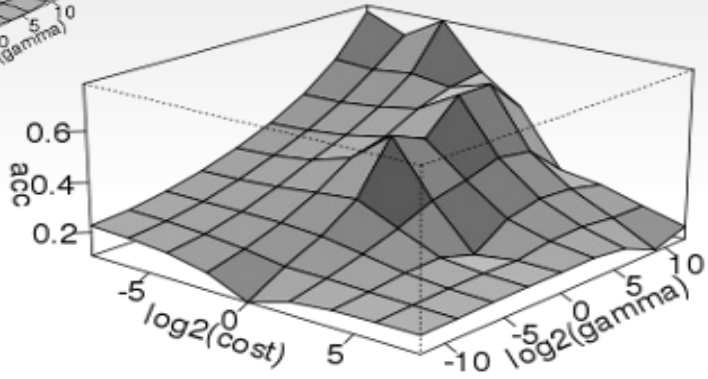
SVM parameter search

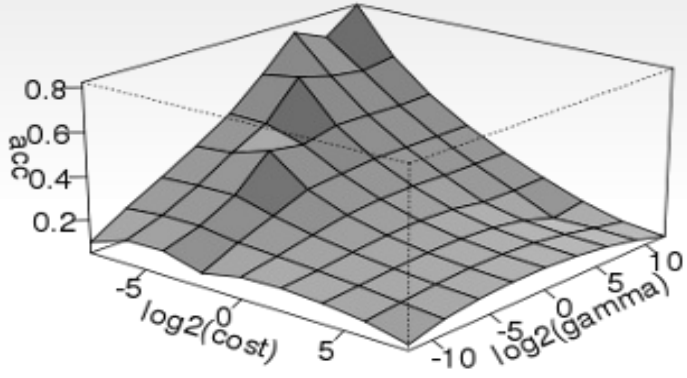


Myopic (13)

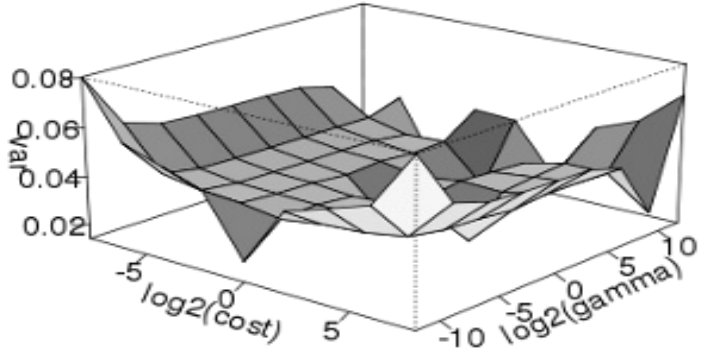
Blinkered (19)

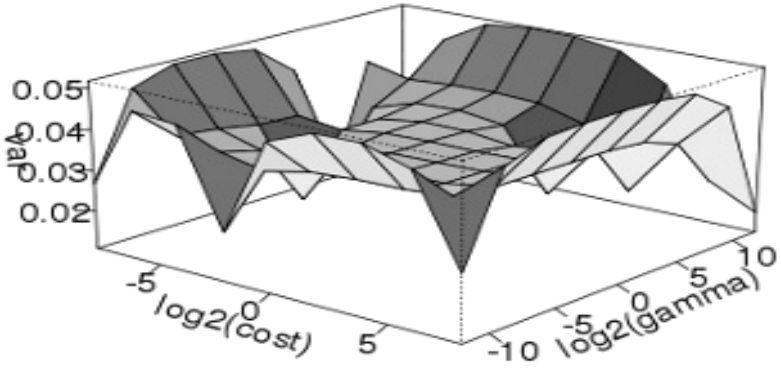
Accuracy





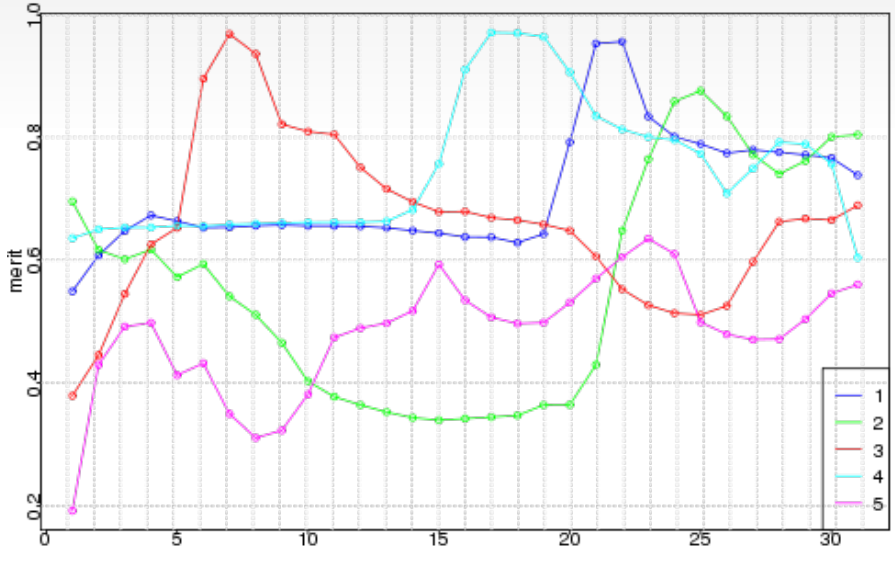
Variance





KLA metrology

Actual data



≈10% of measurements