0.1 EXAMPLE OF KNAPSACK PROBLEM

The "Knapsack Problem" is simple and well known example of the family of NP-complete problems. Here we use the Bayesian Heuristic Approach considering the real data. The greedy heuristic means "pick first the object of largest specific value (relation of value to weight). We optimize the "mixture" of the pure gredy heuristic, the randomized heuristic with probabilities proportional to the specific values and the "pure" Monte Carlo with equal probabilities (see [1])

0.1.1 Data File

The data represents the weights, the values, the numbers, and the names of the inventory items of the "Norveda" shop that sells the "Hitachi" electrical tools. The Table 0.1 shows a fragment of data file 'norveda.txt'.

Weight	Value	Number	Name
3.8	2830	1	CNF35U
10.5	4170	2	CNF65U
11.5	3850	1	CM12Y
1.8	1500	2	CE16
1.7	1500	2	CN16
17.0	2100	4	CC14
20.9	2890	2	J9312N
0.9	330	8	D6SH
1.7	1170	10	D10YA
1.3	630	5	D10VC

Table 0.1 The fragment of data file 'norveda.txt'

In this file:

- on the first line there are the column names
- on the rest of lines there are following fields separated by spaces:
  - the object weight (double)

  - the object value (double)
  - number of the objects (integer)
  - the object name (string)
- there are no empty lines ending the file

0.1.2 Implementing Task

The algorithm is implemented as a *Task* of the GMJG system. Figure 0.1 shows a fragment of the file 'Knapsack.java'

```
public class Knapsack implements Task
{ private double norm_point[];
  private int    number_of_objects;
  public  double total_weight=10;
  private int    object_taken[];
  private float  object_cost[];
  private float  object_weight[];
  private double object_ratio[];
  private Random rnd = new Random();
  public  String data_url = new String("http://norveda.txt");
  private String data_url_old = new String();
```

Figure 0.1 A fragment of the knapsack program

0.1.3 Running GMJG

Figure 0.2 shows the input page which opens starting the applet. On the *Property* fields:

- the *TotalWeight* field defines the weight limit from 10 to 10.000.
- The URL of data file is determined in the field *URL of data file*.

Note that this data file should be on the same server as the applet. If the data is not correct the corresponding field turns red.

On the *Dimension* fields:

- the *Min* field defines the minimal part
- The *Max* field defines the maximal part
- The *Default* field defines the default part

These parts show the proportions of each method in the mixture of three methods of picking objects: Monte Carlo, Randomized Heuristics and Greedy Heuristics.

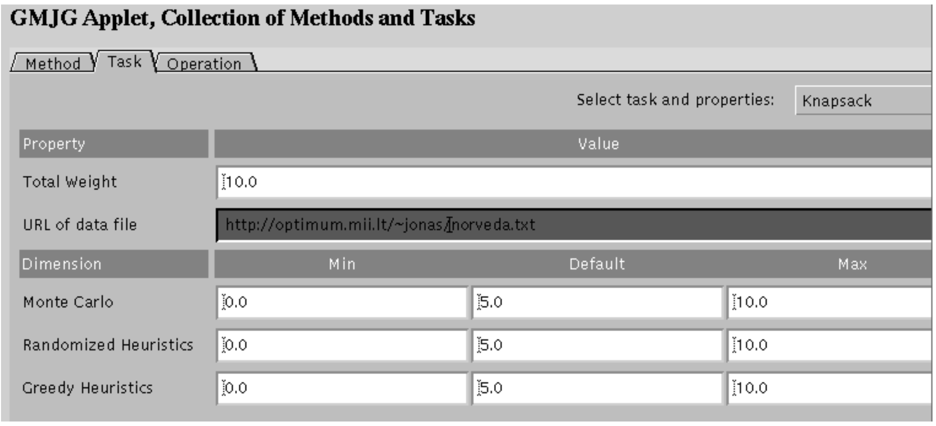

Figure 0.2 Input page

Figure 0.3 shows the output page which opens when the computing is completed. Here *Iteration* means the iteration number where the best value was reached, $F(x)$ defines the best value, "Monte Carlo", "Randomized Heuristics", and "Greedy Heuristics" show the optimal part of each of the three methods in their mixture.

Figure 0.4 shows how the best value changes subject to the iteration number.

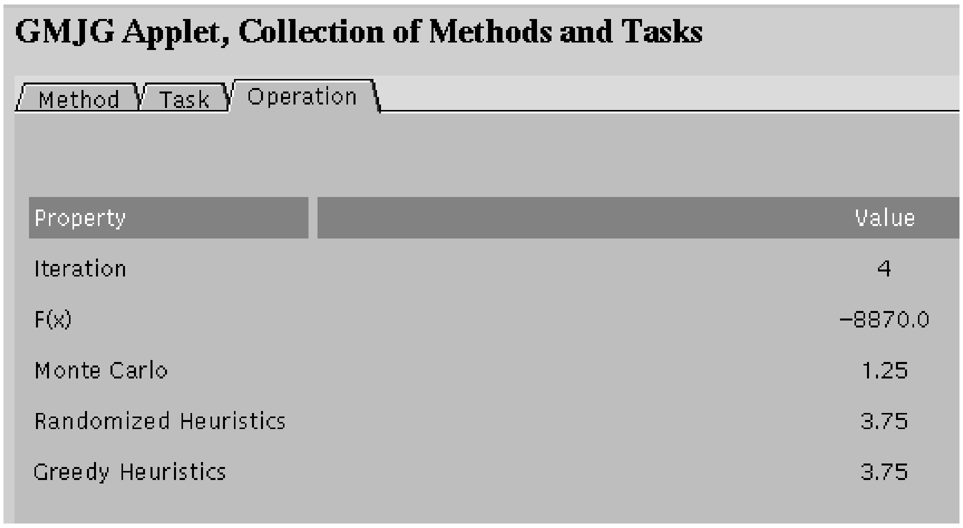

Figure 0.3 Output page

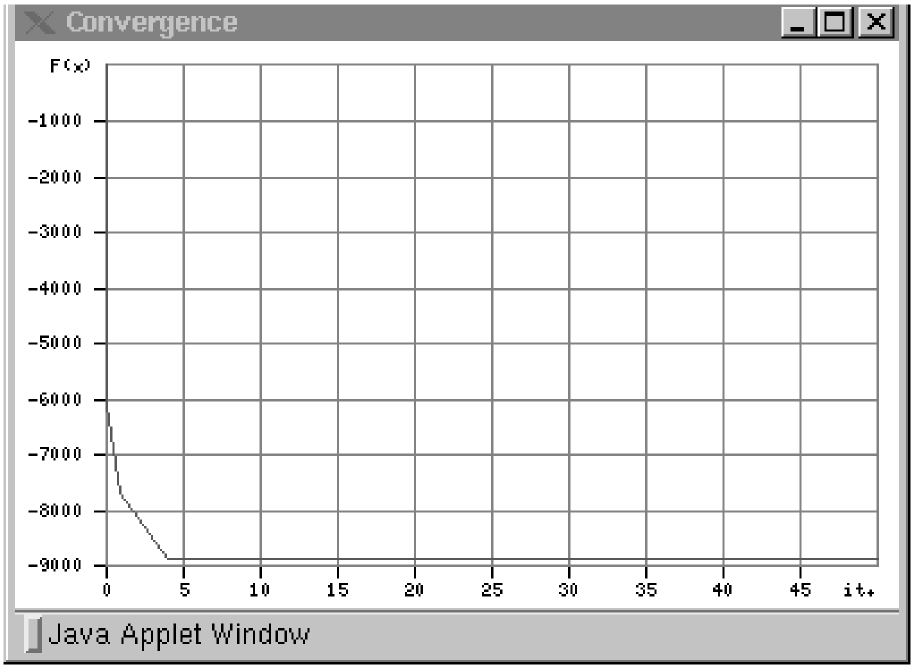

Figure 0.4 Best obtained value subject to iteration number

Figure 0.5 shows how the value changes subject to the Monte Carlo fraction

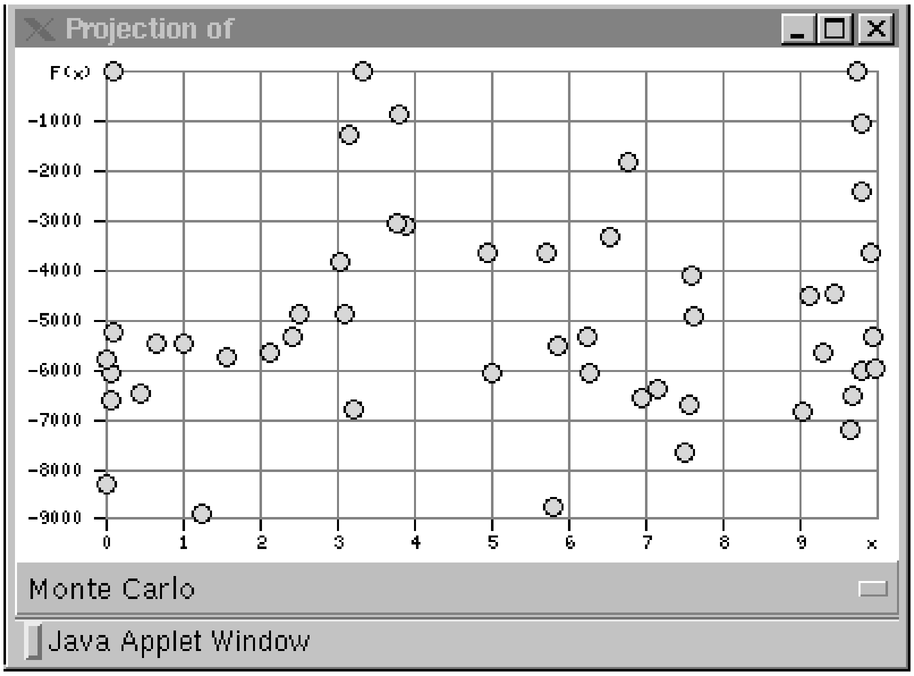

Figure 0.5 Value subject to the part of equal probabilities

Figure 0.6 shows how the value changes subject to the fraction of proportional probabilities.

Figure 0.7 shows how the value changes subject to the fraction of greedy heuristics.

Figure 0.8 shows how the frequency of value depends on the iteration number. Here the different frequency is marked by different grey shades. On the screen that is done by different colors.

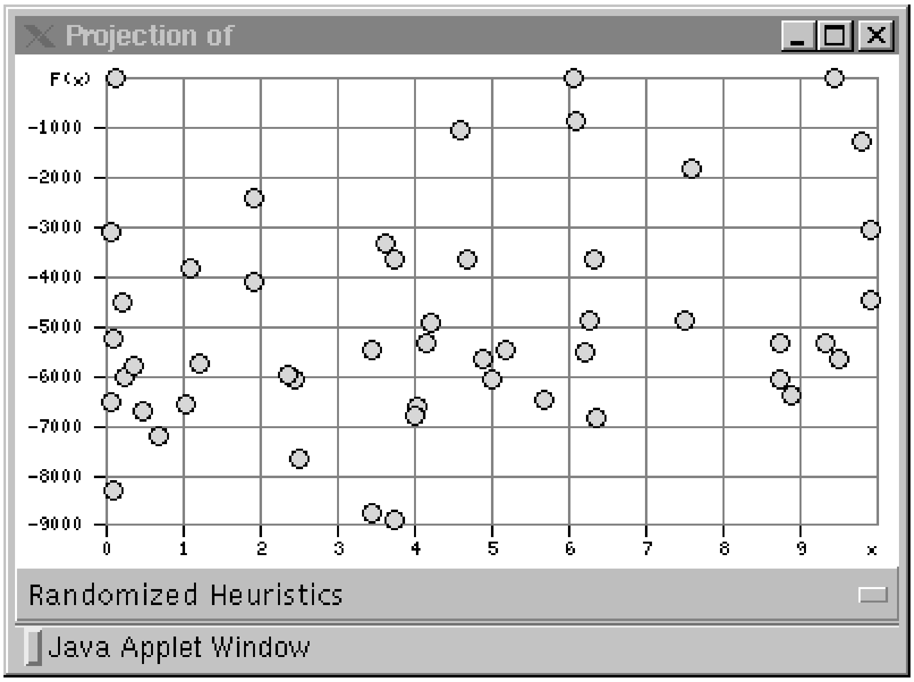

Figure 0.6 Value subject to the part of proportional probabilities

0.1.4 Results

The results table (see Figure 0.9) shows how the results of optimization depend on the optimization method (see the first column), the number of iterations (see the second column), the weight limit (see the third column). The fourth column shows the iteration number where the best value was obtained, the fifth column shows the best value (with minus sign, because the GMJG system is minimizing the objective of the Task object). The sixth, the seventh and the eight columns determine the optimal mixture of three search methods:with equal probabilities, with proportional probabilities, and pure greedy heuristic. These mixtures can be expressed in percentage terms dividing each of the three numbers by their sum and multiplying by 100.

The results suggest that:

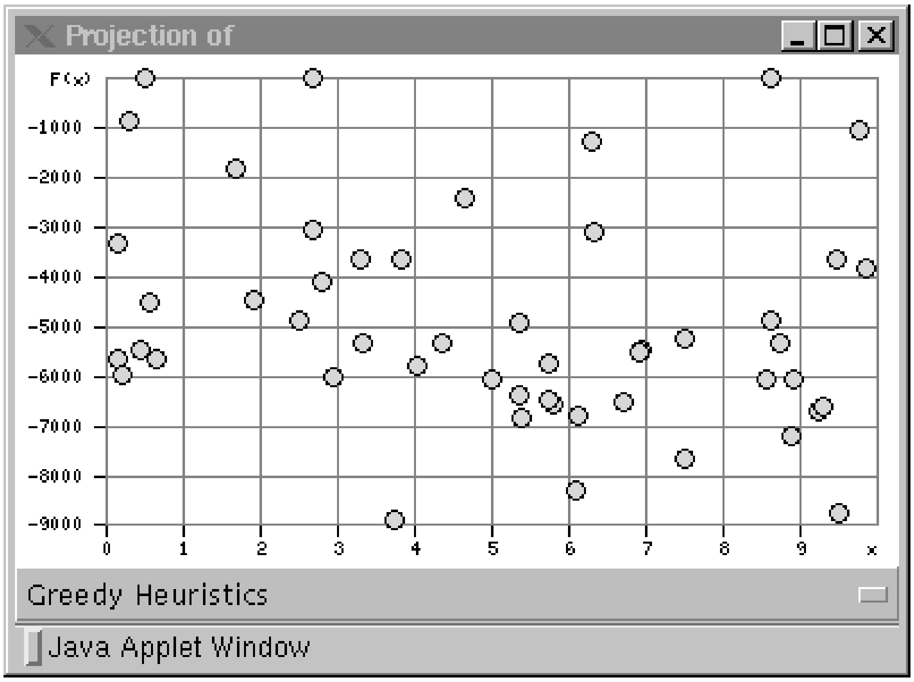

Figure 0.7 Value subject to the part of pure greedy heuristics

- doubling the iteration number (from 500 to 1000) one obtains the average error just 3% lower
- if the weight limit is high then the greedy heuristic is almost useless (the optimal mixture is as 7:7:1 meaning that the greedy heuristics part is just 1/15)
- if the weight limit is low the greedy heuristic is essential (the optimal mixture is as 1:1:4 what means that the greedy heuristics part is ten times greater and equal to 2/3)

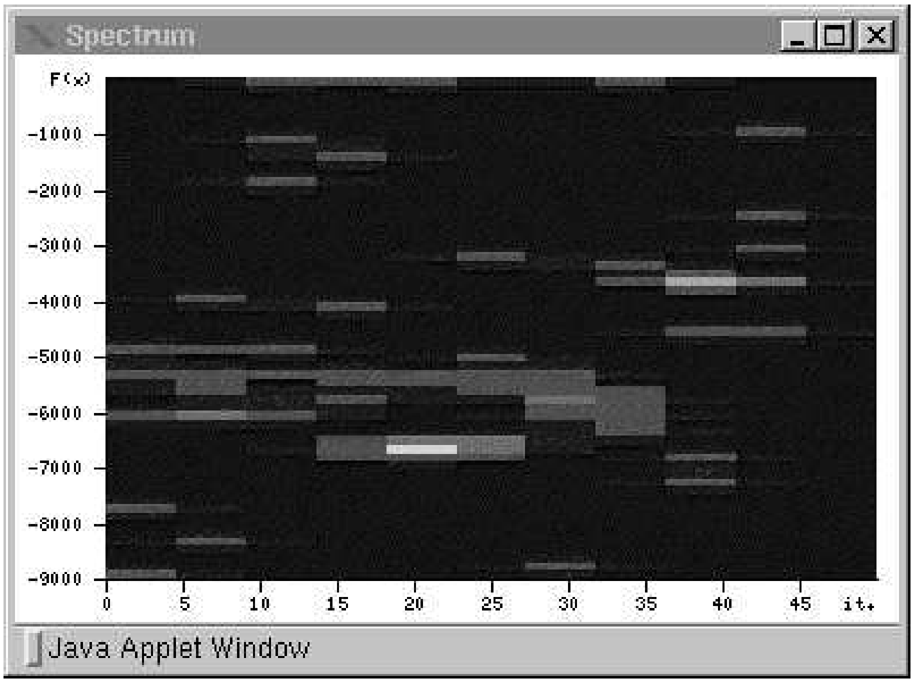

Figure 0.8 Frequency of values subject to iteration number

Method	Iterations	Maximal weight	Iteration number	Objective function	Monte-Carlo	Randomized Heuristics	Greedy Heuristics
Migl	1000	100	535	-66790	1,23	9,297	1,641
			854	-65920	2,576	9,548	8,733
			907	-65660	1,605	9,211	7,882
		1000	932	-488650	0,038	5,4	2,059
			735	-495230	0,047	3,296	0,445
			342	-488710	0,367	9,478	2,953
	500	100	152	-68940	1,237	9,533	6,913
			276	-66340	0,419	9,482	4,172
			269	-70360	4,334	9,528	5,683
		1000	463	-493640	0,103	7,129	1,504
			201	-487240	1,205	5,844	0,093
			439	-483170	2,542	6,819	0,634
Bayes	1000	100	851	-67640	2,731	8,574	9,539
			514	-65090	0,082	5,091	8,761
			595	-67490	1,265	9,508	2,819
		1000	741	-498850	0,473	9,947	0,644
			906	-504300	0,008	7,536	3,259
			949	-505170	0,073	8,612	0,198
	500	100	408	-65850	5,089	7,438	6,707
			213	-66890	0,018	8,213	5,339
			438	-66340	1,244	8,521	8,446
		1000	253	-495000	0,373	8,679	4,233
			37	-499860	0,417	5,745	0,239
			187	-502260	0,012	7,656	1,138

Figure 0.9 Table of results

REFERENCES

[1] J. Mockus, W. Eddy, A. Mockus, L. Mockus, and G. Reklaitis. *Bayesian Heuristic Approach to Discrete and Global Optimization.* Kluwer Academic Publishers, Dordrecht-London-Boston, 1997.