Institut for Matematik & Datalogi
Syddansk Universitet

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JBJ

# DM63 Meta-heuristics — Ugeseddel 3

## Obligatory study advising

In the period September 26 through October 7, we hold studies advising. It is mandatory for all students (except first year students) to come to this studies advising. You sign up at IMADA's secretaries' office (as soon as possible). Please have your picture taken before the advising by showing up at the department (at "vrkstedet") between 12:00 and 14:00 on September 15, 19, or 22. Note that these dates are all prior to the advising period.

## Lecture on September 8, 2005

I briefly covered Branch and Bound for the graph partitioning problem. I introduced the simulated annealing approach and illustrated various (meta)-heuristics for graph partitioning on my computer. We saw that the exact solver (ILOG OPL Studio 3.7) had a hard time solving a graph partitioning problem of size 50, whereas we obtained very good solutions for much larger problems quite fast using the metaheuristics. Of course the point here is that we have no guarantee for the quality of the solutions when we use metaheuristics, but very often (for many problems) they do very well and this is what makes them so useful in practice. I also introduced iterated local search, where we use escape moves to get away for local minima and then continue a new local search. We will return to this simple, but quite often very good, heuristic in a later lecture.

## Lecture on September 15, 2005

We will discuss the paper "Optimization by simulated annealing: an experimental evaluation; part I, Graph partitioning"by D. S. Johnson et al, *Operations research* **37** (1989) 865-892. This is included in the notes as pages 81-108.

I will also discuss Tabu search. Notes pages 20-28 and 163-175 (the last part will not be covered in the lecture, but serves as inspiration and you should read it at some point during the course.) I will also introduce some new problems and discuss neighbours for these.

## Lecture on September 22, 2005

**Note that this will be moved to September 21 at 8-10 in the seminar-room!!!!** I will annonce the topic of the lecture next week.

## Exercises:

1. Experiment with Simulated annealing: Implement a raw simulated annealing algorithm for the graph-partitioning problem and procedures for doing each of the following:
   (a) Finding an initial solution. This could be a random one or a partition found by one of your other algorithms (e.g. the construction heuristic).
   (b) An experimental method for finding a start temperature which gives a sufficiently high initial acceptance ratio.
   (c) A method for generating a random neighbour of the current solution $s$.
   (d) A method for presenting graphically the objective function of the intermediate solutions the algorithm finds. That is, plotting the current best solution for steps of $k$ iterations for some fixed $k$. Here you may use the Unix program "gnuplot". See the manual pages for this comand how to use it.

(e) A method for decreasing the temperature. Here you may simply choose geometric cooling: $T_{t+1} := \alpha T_t$, where $\alpha$ is a real number between 0 and 1.

(f) A method for varying the number of iterations made at a fixed temperature.

(g) A method for varying the stop criterion.

2. Experiment on various test graphs in order to investigate the following things (here it is understood that the given parameter is the only one that you change during the experiment):

   (a) How much does the choice of start temperature influence the quality of the solution found by the algorithm?

   (b) How much does the quality of the start solution influence the quality of the solution found by the algorithm?

   (c) Try to find a good relation between the quality of the initial solution and the initial temperature. I.e. what should the relation be in order to find good solutions?

   (d) How much does the cooling rate influence the quality of the solution found by the algorithm? For this experiment you may start with $T_0 = 2d_{max}$ as suggested by Laursen.

   (e) How many iterations should be taken at each temperature? This clearly depends on the size of the graph and you should try to find a relation ship (see also the paper by Johnson).

   (f) Experiment with the stop criterion. For example try the following posibilities

      i. Stop at a pre determined temperauture. For graph partitioning a neighbour with a higher value than the current solution $s$ will have value at least 1 more and thus the probability of accepting it is at most $e^{-\frac{1}{T}}$. Thus, when $T$ is less than $1/10$ the probability of accepting a neighbour with a higher objective function value is very small and we may stop the search.

      ii. Keep track on the number of neighbours visited since the last improving one and stop if this is above a certain number (to be determined experimentally by you!).

   (g) Try also to "round off" a simulated annealing run by applying (steepest) decent to the result.