GAGP 2009: Assignment 2

This is a marked exercise. It is worth 25% of your course mark. It requires you to write a program and to use it to carry out a number of investigations. You are to write up your investigations in the form of a conference paper with a maximum length of 6 pages. Submit your code and your paper electronically using the submit program:

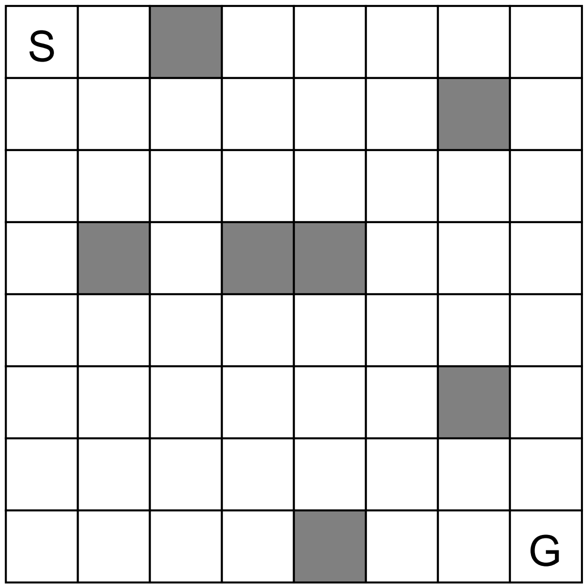
submit ai3 gagp 2 <filename-of-your-paper> <filename-of-your-code>

Please use ai3 even if you are in another year or degree and see the man page for submit if you wish to submit more than two files. Submit your report as a pdf file and your code as a plain text file or files.

You should submit your assignment before 3pm of Friday 27nd November, 2009.

Path planning is an important problem in robotics and operations research. We consider here a simplified version of this problem where a robot wanders around in a grid world. Before the robot is starting to move in a real environment it uses its planning component to run an ant colony algorithm to find a good path. For this purpose, the robot has an exact map of the environment.

The world is a quadratic *N*x*N* array (N>1) and contains *N*-1 randomly placed obstacles, i.e. cells of the grid that cannot be entered (neither by the ant nor by the robot). The robot (and ants) can count cells along their trails and can sense obstacles and any pheromone traces. Next to an obstacle there are fewer choices to move on.



Sample of an 8x8 world containing 7 obstacles.

1. (12/25) Solve the route planning problem by an Ant System for *N*=8.
   a. The robot could use itself as an ant, i.e. it could realize the ACO in the real environment. Would this be a good idea? (Since the robot has some map, it doesn't need to lay pheromones in the real world.)
   b. Discuss termination criteria for the algorithm and choose one which you will be using in the following. Also think about a termination criterion for the individual ants. It is OK if you are not using the simple original ACO algorithm of Dorigo (1991/1992), please state this clearly.
   c. How does the computing time scale with the complexity of the problem? Run the algorithm for different problem sizes and present the results for run time until termination vs. *N* in suitable plots. A log-linear plot or a log-log plot might be helpful to identify a trend. It is not the idea to produce a reliable statement on the asymptotic (i.e. large *N*) performance, but to be able to *extrapolate* to the range of problem sizes that could be possibly done with your computer.

2. (6/25) Use also a canonical GA to solve the same problem. The individuals are strings of four-valued characters encoding the possible movements: **D**own, **L**eft, **U**p, **R**ight (or, if you prefer more biological abbreviations, "**A** step down", "**G**o left", "**C**limb up", "**T**urn right"). While the ants in the first problem simply have fewer choices to continue, in the GA you should enforce obstacle avoidance via the fitness function or perhaps by editing.
    a. How do set up the GA (length of the strings, operators, a simple fitness function etc.)?
    b. What "stepping stones" could you use for the definition of a fitness function that produces more quickly effective[1] movement plans or to increase the speed of improvement of the individuals?
3. (6/25) Compare the performance of the ACO and the GA. Additional simulations are not required here.
    a. Both for ACO and GA, parameters can be tweaked and the implementation can follow one out of a large number of algorithmic variants. Discuss whether your result in the previous tasks might have been qualitatively different for a different choice of the particular variants of ACO and GA. For example, variable string lengths might be a good idea for GA or using only the best ant for pheromone update in ACO.
    b. Can either of the ACO or GA be easily improved by local search?
    c. Briefly describe an approach to the present route-planning problem that is unrelated to meta-heuristic search. Do you expect this approach to perform better than ACO or GA?
4. (1/25) Formulate the main points of your results as a brief conclusion.

Bear in mind that you will be using random number generators and that, to get a representative performance and results that are statistically significant, you will need to run each experiment several times. See Appendix A of the previous years' lecture notes for information on experiments and statistics.

Your paper should describe the experimental design (i.e. what the experiments are and what they are intended to show), the results, and discuss the results in the light of the task. Use tables and figures where appropriate. Make sure that the code contains a concise description of its design.

The following criteria will be used in evaluating your assignment:

- Is the design of the algorithm sound?
- How clearly are your design and implementation described?
- How sound are the experiments and how good are the results obtained?
- To what extent did your experiments give the ACO and the GA "a good workout"?
- Does the discussion of your results shed light on how the ACO works as you vary the parameters and undertake the tasks of varying difficulty?

Additional tasks ;-)

- Browse through the collection of resources at http://www.aco-metaheuristic.org/. There you should be able to find the relevant papers on ACO. See lecture slides for more information.
- Have a look at the citation numbers at the bottom of the page http://www.hant.li.univ-tours.fr/artantbib/artantbib.php
- Play with the applet at http://www.djoh.net/inde/ANTColony/applet.html (You may need to help the ants by creating some walls by clicking in the playground)

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[1] An effective plan connects the starting position and the goal. An efficient plan does with using short path. An optimal plan states the shortest route (or one of several shortest routes) from start to goal.