COURSEWORK ASSIGNMENT 2

Introduction

In this second 4M17 coursework exercise you will investigate the performance of two of the methods introduced in lectures on a problem that is easy to describe but harder to solve.

This assignment counts for 50% of your final grade for 4M17. You should expect to spend 16 hours on it. Time spent reading email or surfing the web while your code runs in the background does not count!

The Problem

The problem you will be attempting to solve is the *Eggholder Function*. This is an *n*-dimensional constrained optimization problem defined as follows:

Minimize $f(\mathbf{x}) = \sum_{i=1}^{n-1}\left[-(x_{i+1}+47)\sin\left(\sqrt{\left|x_{i+1}+\tfrac{1}{2}x_i+47\right|}\right)-x_i\sin\left(\sqrt{\left|x_i-x_{i+1}-47\right|}\right)\right]$

subject to $-512 \le x_i \le 512$

The 2-dimensional form of this problem, which is the only one easy to visualise, is therefore:

Minimize $f(x_1,x_2) = -(x_2+47)\sin\left(\sqrt{\left|x_2+\tfrac{1}{2}x_1+47\right|}\right)-x_1\sin\left(\sqrt{\left|x_1-x_2-47\right|}\right)$

subject to $-512 \le x_1 \le 512$

$-512 \le x_2 \le 512$

As shown overleaf in Figure 1, this is a problem with multiple local maxima and minima and a global minimum at a constraint boundary. It is therefore a hard optimization problem to solve.

On the plus side, however, all the control variables are of the same type (continuous variables) and have similar (in fact, identical) scales, all the constraints are inequality ones (and indeed just bounds) and the feasible space is not disjoint.

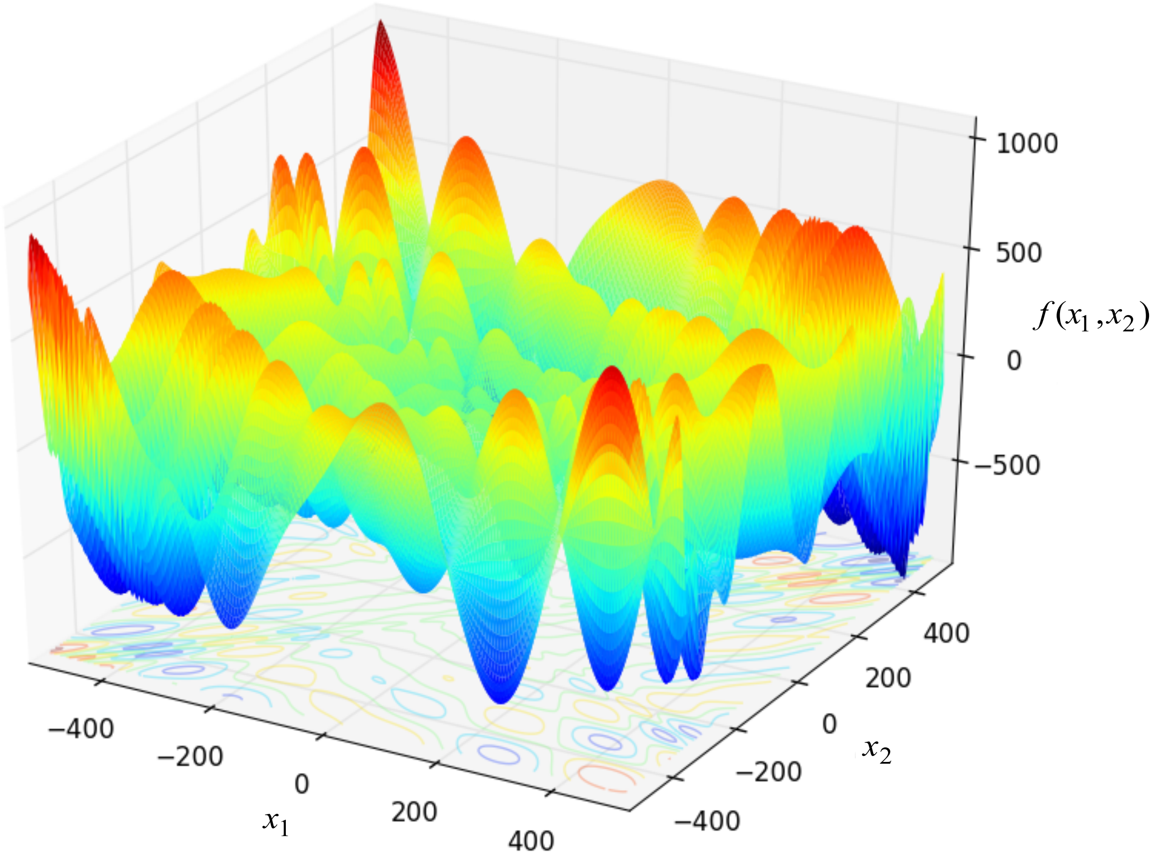


Figure 1: A 3D plot of the Eggholder Function for $n = 2$.

Coursework Tasks

The aim of this coursework exercise is to compare the performance of two of the optimization algorithms you have learnt about in 4M17 on the **5-dimensional** version of the Eggholder Function (5D-EF).

One of the algorithms **must** be one of the methods covered in Dr Parks' lectures (i.e. Simulated Annealing, a Genetic Algorithm, an Evolution Strategy or Tabu Search); the other algorithm can be another of these methods or another stochastic global optimization method (e.g. Particle Swarm Optimization). The option allowing your own choice of the second optimizer is particularly geared towards Part IIB students who might be using such a method in their MEng project and postgraduate students who might be using such a method in their research.

You may **either** write your own optimization codes **or** find and use suitable (free) software on the internet, or indeed write one code and find the other. Links are provided to some resources in the *Assignment 2 Resources* section of the 4M17 Moodle site. You are not restricted to using these, however.

Any popular programming language (MatLab, C++, Python, Fortran etc.) can be used.

You should only use software from the web for which you can obtain the source code, e.g. the uncompiled C++, to enable you to debug it if necessary and perhaps to modify it if it does not do exactly what is required.

Investigate the performance of the algorithms you have sourced or implemented on the 5D-EF. Allow 10,000 objective function evaluations in each algorithm run you execute. In analysing the performance of the algorithms, bear in mind the comments made on performance measures in the *Common Issues* section of the lecture notes.

Investigate the effects on the performance of your algorithms of varying some of the parameters or implementation options that control them; for instance, for a Genetic Algorithm investigate the effect of different population sizes/numbers of generations, or different crossover and mutation probabilities, or different selection schemes etc. An exhaustive exploration of all possibilities is not required, just some systematic examination of the way in which the control parameters affect algorithm performance.

If you are using a code you have found, as opposed to one you have written, rather more investigations will be expected.

In these studies the same set of random number generator seeds should be used in each set of runs.

For population-based search methods (i.e. Genetic Algorithms and Evolution Strategies), the initial populations should be generated by random sampling; initial populations should not be "seeded" with solutions close to the global optimum.

For search methods that start from a single solution, the initial solution should be randomly generated and varied from run to run.

Final Report: Submission

Write a report detailing and analyzing the results of your investigations. This report should be uploaded as a pdf document via Moodle by 4pm on the first day of Lent Full Term, **Tuesday 16th January 2018**.

You should also deliver a completed coursework coversheet **in hard copy** to Dr Geoff Parks (CUED room BS3-02) by the same deadline. Only the coversheet is required in hard copy. The report itself should be submitted via Moodle.

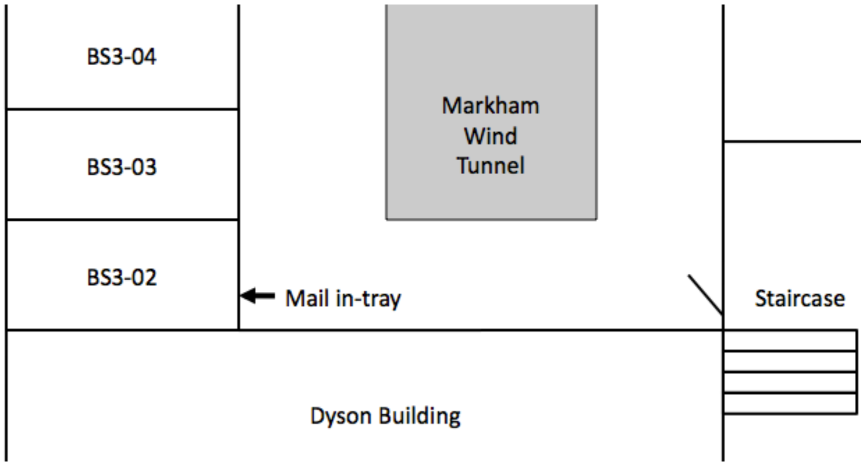
Part IIB students should **only** include their Coursework Candidate Numbers (CCN), and must ensure that their names do **not** appear in the report or in any of the file names or code listings.

MPhil students who have been given an anonymous identifier similar to a CCN should use that, and must ensure that their names do **not** appear in the report or in any of the file names or code listings.

Other postgraduate students should ensure that their names and CRSIDs are included on their reports.

A specially prepared coursework coversheet for this exercise is available from the *Assignment 2* section of the 4M17 Moodle site.

Room BS3-02 is on the Baker Building South Wing 3rd floor. Its location and the location of the mail in-tray are shown in the schematic below:



Final Report: Content

- ☐ The report should include (in Appendices) listings of the source code of the algorithms you have implemented or found. The listings of codes you have written should be reasonably well commented. The source (e.g. the url) of any found codes should be clearly identified.
- ☐ Detailed descriptions of the ways in which the algorithms work are not required. If you have implemented an idea of your own (**which is by no means discouraged**) or used a feature not described in the 4M17 lecture notes – perhaps one included in a code you found – the basic principles of this should be explained in your report.
- ☐ Your report should discuss problem-specific implementation details, such as how you have chosen to handle the constraints.
- ☐ You should include in your report figures showing representative examples of the search patterns followed in (x_1, x_2) space by the two optimization methods you have tested when tackling the **two-dimensional** Eggholder Function (2D-EF). Such figures are useful for confirming that the algorithms are performing as expected.
- ☐ The main focus of your report should be an evaluation of the performance of the two methods you have applied to the 5D-EF, and a discussion of the effects on this performance of changing the algorithms' control parameters or implementation details.

Final Report: Marking

The mark awarded will depend on:

- how well written any code you have written is (lack of bugs, well commented),
- the quality of the computational experiments and investigations undertaken,
- the quality of presentation with a particular focus on the presentation of data/results,
- and the quality of performance analysis/comparison and discussion.

Practical Issues

Demonstrator Help

Apart from the scheduled coursework session you will be expected to work independently.

Questions related to the methods being investigated should be directed in the first instance to Dr Geoff Parks (email: gtp10@cam).

Questions about the final report or any other logistical matters should be directed to Dr Geoff Parks (email: gtp10@cam).

Computer Usage

As the problem functions (objective and constraints) for the problem to be solved are simple mathematical functions and the number of iterations allowed in each run is quite small, the running of the algorithms you write or find should not be very expensive computationally, and you should be able to do so on-line on the CUED Teaching System without offending anyone. Obviously, if you have access to good computing facilities of your own or through your College or research group (in the case of postgraduate students), it may be more convenient to use these. If your laptop is up to the task, feel free to use that.

When you come to investigate the effects of changing the control parameters of your algorithms and need to do series of runs where only the random number seeds are being changed, you may find it more convenient to run these using a script. For specific advice/ instructions you are referred to the relevant page on the CUED help system:

www-h.eng.cam.ac.uk/help/unix/LongRunningPrograms/

Summary

Key Dates

Friday 17 November 2017	10–11am	Coursework Introduction	LR3
Friday 24 November 2017	1–2pm	Coursework Session	DPO Clusters 7 and 8
Tuesday 16 January 2018	4pm	Report Submission Deadline	via Moodle