NAT & NAT-DL 2022/2023: Assignment[1]

Natural Computing

This is an exercise worth 40% of the course mark. The maximal score you can get for the assignment is 100 points. The assignment is to be completed by yourself individually. You are asked to submit an individual solution, and not to discuss or share your solution with other students. The assignment requires you to write a program in Python (which can be a Jupyter Notebook), and to use it to carry out a number of investigations. You are to submit your program code and a report. It will be helpful, if you include some comments in your code, but there will be no marks specifically for the code, see the marking breakage below.

Task description

Problem 1: Analysis of Particle Swarm Optimisation (25 points/100 points)

Analyse the behaviour of the standard PSO algorithm for minimisation of these two functions:

Sphere function: $f_1(x)=\sum_i x_i^2$, where x=(x_1, ..., x_d), and $x_i \in$[-5.12, 5.12],

Rastrigin function: $f_2(x)=10d+\sum_i (x_i^2-10\cos(2\pi x_i))$, where $x=(x_1, ..., x_d)$, and $x_i \in$[-5.12, 5.12],

1. Find parameters α_1, α_2 and ω with which the standard PSO algorithm can obtain good results in a short time. It is recommended to set $\alpha_1 = \alpha_2$ and to consider only the parameter $\alpha = (\alpha_1 + \alpha_2)$ in addition to ω. Set the search space dimension *d* to a value larger than 2, and define (and justify) a termination criterion that is appropriate for this task. Discuss how do the obtained parameter values differ for the two objective functions.

Problem 2: Scaling (25/100)

2. Choose one addition parameter: The number of particles *N*, the search space dimension *d*, or the total number of fitness evaluations *T* per run. Discuss how you evaluate the outcome and how the results for the two functions depend on the chosen parameter.

Problem 3: Heterogeneous particle swarms (20/100)

3. Modify the PSO by introducing two types of particles that are characterised by different parameters sets α_{11}, α_{21}, ω_1 and α_{12}, α_{22}, ω_2. For a population of *N* particle, *N*/2 will be of one and *N*/2 or the other type. Choose suitable values for these parameter sets as well as for *N*, *d*, and *T*, and test the performance on the Rastrigin function.

Problem 4: Differential evolution (15/100)

Implement the differential evolution algorithm (DE)[2] and compare its performance with the PSO based on the Rastrigin function.

Problem 5: Genetic Programming (15/100)

Generate a dataset from the Rastrigin function, and use a GP to reproduce this function from this data set. It is recommended to use a smaller dimension $d<3$ for this task. You can restrict the set of numerical values to the relevant numbers (10, 2, d, π).

1 The text of this final version is unchanged from the first update of the preliminary version.

2 Storn, R. and Price, K., 1997. Differential evolution – A simple and efficient heuristic for global optimization over continuous spaces. *Journal of Global Optimization*, *11*(4), pp. 341-359.

You may find the following comments and questions useful for your solution of the assignment

How do you decide about the termination of a single run, and how on repetitions of runs?

If you need to choose values of parameters of the algorithms, can you explain and justify how you came to this choice?

If you perform comparisons, make sure that the comparison is fair, and discuss your evaluation procedure.

Wherever appropriate, use graphical representations of your numerical results.

Although the space is limited, try to include justification and explanation of your work, rather than just a list of the steps that you have performed.

Structure of the report

In the report on your work on this assignment use a separate page for each of the four questions. If you choose to add a front page or a general introduction, restart the page numbering such that Question 1 is on page 1, Question 2 is on page 2 etc. If you need to include more material, please use an appendix, but consider that your report needs to be concise.

Feel free to use any existing resources and literature to prepare your work and to support your argument, but make sure to cite all papers and resources that you have used for this assignment. Place this list of references after the last text page, it will not count towards the page limit.

Submit your report as a PDF file and your code as a separate zipped file (use zip or gzip) via Learn.

Deadline for submissions is **12noon of Thursday, 17. November 2022.**

In the tutorial sessions and in the classroom Q&A sessions will be time to clarify your questions related to the assignment. For critical questions, please contact michael.herrmann@ed.ac.uk directly.