UNIVERSITY OF PRETORIA
DEPARTMENT OF COMPUTER SCIENCE

COS710: Assignment 1 (Particle Swarm Optimization)

Due date: 25th February 2019, at 23:00

Do any one of the assignments listed below. Note that you have to submit a pdf document, containing a technical report wherein you describe what you have done, present and discuss your results. Find at the end of the assignment specifications guidelines for writing your report. You are also required to uploaded your source code and raw data.

Option 1: Particle Swarm Optimization: Intelligent Parameter Tuning

As with many optimization techniques there are a number of control parameters that need tuning. In PSO the optimal choice of inertia weight, cognitive coefficient, and social coefficient are known to be very problem dependent.

In practice there are a number of ways to approach parameter tuning, from the simplest approach of testing all combinations of parameters, from a subset, in a brute force manner (often refereed to as a factorial design) to more intricate approaches like F-Race and iterated F-Race. See `http://code.ulb.ac.be/dbfiles/BalBirStu2007hm.pdf` for a summary.

The mentioned approaches assume no or little knowledge on the parameter space. However in the context of PSO there does appear to be an underlying structure to the parameter space that is easily exploitable. Specifically, in figure 1 it can be seen that the structural characteristics of the parameter space imply that some type of local search would be effective. Note that the landscape depicted in the figure is built up from the averages over the whole CEC 2014 benchmark suite, however the same macro-level structure is present for each objective function when analyzed individually, the optima however can change.

For this assignment you will need to devise an effective and simple search method for finding the optimal PSO coefficients (c_1, c_2, w), which relies on the structural information we have just discussed. Your approach may use at most 1 control parameter.

For this assignment you must use.

- Topology: Star
- Swarm size: 20
- Dimension: 20
- Iterations: 1000
- Boundary handling: Do not update the personal and neighborhood best positions if they violate the search boundary.

In order to test the effectiveness of your newly found parameters (after the search process) you will need to compare them against a set of other parameter. Specifically, for every objective function you need to calculate how well the PSO does for all parameters within the region

$$w \in [-1.1, 1.1] \text{ and } c_1 + c_2 \in (0, 5], \tag{1}$$

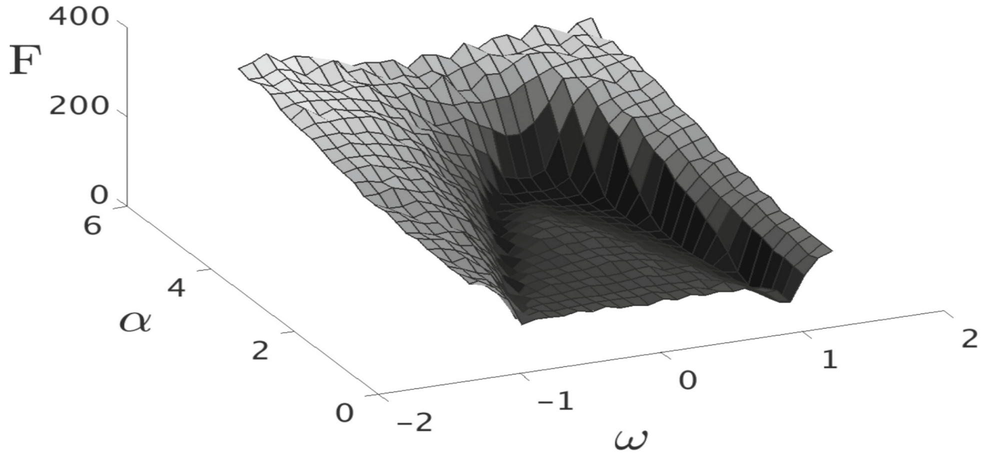

Figure 1: Average performance over CEC 2014 benchmark suite

where $c_1 = c_2$, with a sample point every 0.1 along w and $c_1 + c_2$. Note that for each sample point you need to run 30 independent runs. Now in order to ascertain whether you found good parameters, you must rank the means of each sample point from equation 1, and report where your found parameter set would rank.

You must also report how many function evaluations your search technique used. To clarify, the function your search technique is trying to optimize is in fact a run of PSO algorithm using a set of coefficients.

The objective function the underlying PSO should optimize are

- Spherical
- Ackley
- Michalewicz
- Katsuura

You can find formal definitions of each function from `http://ieeexplore.ieee.org/document/6855840/` (login via the library to access).

Option 2: Particle Swarm Optimization: Classic versus "State of the Art"

Since PSO's inspiration there have been numerous variants of PSO proposed. For a PSO practicer it becomes a challenge to pick the "best" PSO. A variant of PSO, which attempts to include numerous improvements to PSO, is standard PSO 2011 (SPSO2011), as proposed by Clerc, `http://clerc.maurice.free.fr/pso/SPSO_descriptions.pdf`. Your task for this assignment is to empirically compare PSO with just the inertia weight, against the full SPSO2011 on the following 9 objective functions (you must parameter tune for each function).

- Spherical
- Ackley
- Michalewicz
- Katsuura
- Shubert
- Ackley (shifted and rotated)
- Michalewicz (shifted and rotated)
- Katsuura (shifted and rotated)
- Shubert (shifted and rotated)

You can find formal definitions of each function from `http://ieeexplore.ieee.org/document/6855840/` (login via the library to access). You may also refer to the CEC2014 benchmark problem definitions, for an explanation of how to shift and rotate the objective functions.

For this assignment you must use for, both PSO and SPSO2011:

- Swarm size: 20
- Dimension: 20
- Iterations: 1000
- Boundary handling: Do not update the personal and neighborhood best positions if they violate the search boundary.

In order to perform a comparison you will need to run each algorithm at least 30 times, and then perform the Mann-Whitney U statistical test to check if there is a statistical significant difference between the two algorithms, and if so, to test whether one is better or worse than the other.

Marking and general guidelines:

For this assignment you have to submit a research report where you discuss your findings. For this assignment your reports must follow the IEEE conference format `www.ieee.org/conferences/publishing/templates.html`, you may use the Latex or the Word template, however the it will serve as good academic writing practice to utilize latex. There is also a page limit of 8 pages for this assignment. Given the imposed two column format it would require a substantial amount of writing to exceed this limit.

This is not a course in technical and report writing; however, you should at least attempt to follow some accepted document writing techniques and to make your report as readable as possible. You are more likely to obtain a higher mark if your report generates a good impression with the marker and is void of general errors like spelling and grammar mistakes.

You are strongly advised to download some research papers from the CIRG members to get a feel for how to write a report. A quick search on through Google Scholar should yield good results.

The following is a general guideline of how to structure your report; however, strict adherence to this guideline is not a requirement for this assignment.

1. Abstract:

The abstract should briefly summarize the purpose and findings of the report.

2. Introduction:

The introduction sets the stage for the remainder of your report. You usually have very general statements here. The introduction prepares the reader for what to expect from reading your report. In general, the introduction should either contain or be a summary of your ENTIRE report.

3. Background:

A very high level discussion on the problem domain and the algorithms and/or approaches that you have used. Do not be too specific on the algorithms and approaches. This section is typically where the "base cases" of concepts that appear throughout the remainder of your report are discussed. It is also an ideal place to refer a reader to other sources containing relevant information on the topic but which is outside the scope of your assignment. It is the perfect place for pseudo code. Remember to discuss very generally. After reading this section the marker should be able to determine whether or not you know what you're talking about.

4. Implementation:

In this section you discuss how you approached, implemented and solved your assignment choice. Mention, for example, the values set for the algorithm's control parameters, how many simulations you have run and what the characteristics for candidate solutions to your problems are. After reading this section (in addition to the background) the reader should be able to duplicate your experiments to obtain similar results to those obtained by you. This is also the section where your discussion specializes on the concepts mentioned in the background section. Be very specific in your discussions in this section.

5. Research Results:

This is the section where you report your results obtained from running the experiments as discussed in the implementation section. You have to give, at least, averages and standard deviations for the experiments/simulations. Thoroughly discuss the results that you've obtained and reason about why you obtained the results that you have. Answer questions like "are these results to be expected?" and "why these results occurred?" and "would different circumstances lead to different results?".

6. Conclusion(s):

Very general conclusions about the assignment that you have done. This section "answers" the questions and issues that you've raised and investigated. This section is, in general, a summary of what you have done, what the results where and finally what you concluded from these results. This is the final section in your document so be sure that all the issues raised up until now are answered here. This is also the perfect section to discuss what you have learnt in doing this assignment.