### C:\Dropbox\DMU\Lessons\IMAT 1221-2 - Linear Algebra I - II\Phase Tests\2018-2019\Phase Test - Resit\dmulogo.pngCSIP5304 - Fuzzy Logic & Evolutionary Computing

### MSc Artificial Intelligence, 2023-2024

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# Final Report - Evolutionary Computing

## Problems

You must solve two problems, one unconstrained and one constrained.

#### Unconstrained Problem

Select **one problem** from the GA/PSO/DE presentation slides, i.e.

* + the Rosenbrock function,
  + the Himmelblau function,
  + the Rastrigin function, or
  + the Ackley function.

Wherever you can select the number of variables, i.e. Rosenbrock or Rastrigin function, select nVar = 2.

#### Constrained Problem

Select **one problem** from the Constraint Handling Techniques presentation slides, i.e. one of the four mathematical constrained problems, namely:

* + the Constrained Himmelblau problem,
  + the Constrained Rosenbrock problem,
  + the Constrained g06 CEC 2006 problem, or
  + the Constrained g08 CEC 2006 problem,

**or** one of the three real-world problems, namely:

* + the Milling Process problem,
  + the Welded Beam Design problem, or
  + the Two-Bar Truss Design problem.

Select **one constraint handling technique** from the homonymous slides, i.e.

* + the Static Penalty,
  + the Dynamic Penalty, or
  + Deb’s Approach.

**Note: If you select one of the four mathematical constrained problems, the objective function must be different from the objective function of the unconstrained problem you have selected.**

## Methods

Solve each problem with **three different methods**:

* + Real-Coded Genetic Algorithm,
  + Particle Swarm Optimisation, and
  + Differential Evolution method.

For each of the six problem-method combinations, and for the specific combination of parameters values, operators, techniques, and variants, explained in section 3, find the minimum number of iterations needed so that the absolute error of the best solution is below a user defined tolerance, e.g. 10^(-2). For the evaluation of the error, use the theoretical/reference global minimum of each problem, also provided in the slides. Repeat the experiment several times and take the median value of the number of iterations needed. For the problems that have two independent variables, i.e. the four unconstrained problems and the four constrained problems, provide some contour plots on the x-y plane, showcasing the progression between the stages of the evolution, at different number of generations.

The parameters, operators, techniques, and variants of the three methods are shown below.

#### Real-Coded Genetic Algorithm

* + Parameters: maximum iterations, population size, crossover probability, mutation probability, and any additional parameters used in the operators.
  + Operators: selection, crossover, mutation, and survivor.

You may use the analysis and results from Weekly Exercises 1, if appropriate, for the operators that may be common with the Binary-Coded Genetic Algorithm, e.g. selection and survivor, and further investigate the other operators and parameter values in terms of performance.

#### Particle Swarm Optimisation

* + Parameters: maximum iterations, population size, inertia coefficient, personal acceleration coefficient, social acceleration coefficient, and any additional parameters used in the dynamic/advanced techniques.
  + Dynamic techniques: damping factor for the inertia coefficient.
  + Advanced techniques: constriction coefficients.

You may use the analysis and results from Weekly Exercises 2, if appropriate.

#### Differential Evolution method

* + Parameters: maximum iterations, population size, scaling factor, crossover probability and its range, and any additional parameters used in the variants.
  + Variants utilising x/y/z strategies.

You may use the analysis and results from Weekly Exercises 3, if appropriate.

## Effect of parameters, operators, techniques, and variants

* For each of the three methods, report the effect of different values of parameters, operators, techniques, and variants, which are mentioned in the previous paragraphs, and state the combination for the most efficient combination.
* Use at least two different operators, techniques, and variants for each type when comparing (four operator types for RGA, two techniques for PSO, two x/y/z strategies for DE).
* If you observe behaviours that differ between the unconstrained and the constrained problems, state the differences.
* Demonstrate why this combination is the most efficient for each problem (or both).
* Determine which parameters, operators, techniques, and variants have the highest impact on the efficiency, and which have the lowest.
* Determine the effect of the constraint handling technique parameters and examine whether the constraints of the final best solution are satisfied or not.

## Comparison, Interpretation and Conclusions

* For each problem, compare the three most efficient methods of each type (one RGA, one PSO and one DE). Compare the efficiencies for the tolerance which you based your analysis on.
* How well the best methods (without re-tweaking the parameters) perform if we change the tolerance? Interpret your findings.
* How does the constraint handling parameter affect the results?
* Report on the common and different behaviours between the methods.
* Interpret the results, draw conclusions, and provide recommendations for further improvement.

## Important notes

* Create a report that answers the above questions.
* As a guide you should aim to make the report around **15 sides of A4** (using Arial font and minimum size 11) and between **2000-3000 words**, including appendices. We will not impose a penalty for reports that are too long or too short, but this is intended to be a technical report and it should present the work in a concise but detailed manner.
* Use headings for sections and subsections with bold typeface, clearly stating the content, e.g. “RGA - Constrained Himmelblau problem” for a section heading, or “*μ*+*λ* and *μ*, *λ* Selection Operators” for a subsection heading.
* The code, output, if used, and some additional graphs can be included in an appendix, however the main part of the project, which includes the text and the main graphs, should independently provide the main points.
* The modified code should be copied as text, as opposed to an image, in the report and also as separate .m files.
* The graphs should be clear and have titles, axis labels, legends etc.
* The provided code should be considered as a good starting point, and is subject to improvement, especially on the documentation.
* Improve the readability (e.g. add some comments in commands, variables, and functions to explain what they do, even those included in the original code).
* Ensure that the code has optimum performance (e.g. avoid calculating the same formulas more than once where not necessary).
* Make the programme as parameterised as possible. This means that any constant should be defined in the main script file once, and then only the variable name should be passed to the functions.

## Deliverables

* You should submit your report via VLE > Final Report by the provided deadline.
* Please submit directly, using multiple files if needed, rather than in a compressed file.

## Marking Scheme for Evolutionary Computing – Final Report

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| --- | --- | --- | --- | --- | --- |
| **Criteria** | **0-44%**  **Fail** | **45-49%**  **Marginal Fail** | **50-59%**  **Pass** | **60-69%**  **Merit** | **>70%**  **Distinction** |
| **C1. [20%]**  **Description and implementation of problem, method, tolerance, median etc, documentation of the code.** | Not acceptable. | Some attempt but with serious limitations. Poor implementation or little/no evidence of the implementation in the report. No documented code. | Good effort but with notable limitations. The methods solve the problems to a reasonable level. The results are presented reasonably clearly. | Very good implementation of problem, method, tolerance, median etc. Only minor limitations. You have produced a working implementation that produces good results. | Excellent, showing a sound understanding of topic. You have produced a working system that produces the desired and best results. |
| **C2. [40%]**  **Investigation of effect and tuning of different values of parameters, operators, techniques, and variants.** | Very little of value. | Weak, with substantial limitations. No alternative operators, techniques, or variants. Some effort evident with not clear conclusions. | Some good work, tried some different parameter values or some operators, techniques, and variants with some understanding evident. | Very good work. Competent investigation of the effect and tuning of different values of parameters, operators, techniques, and variants. Only minor limitations. | Thorough and complete, well documented, excellent approach. |
| **C3. [20%]**  **Method comparison, interpretation, conclusions, recommendations for further improvement.** | Missing or poor or not meaningful. | A minimal attempt with serious limitations. Shows little understanding. | Satisfactory - good, but with some notable limitations. Lacks depth. | Very good, comprehensive, with good explanation of the efficiency of each method, and their common and different behaviours. | Excellent, follows logically from body of report and contains excellent and original interpretation, conclusions, recommendations for further improvement. |
| **C4. [20%]**  **Structure, presentation and use of graphs.** | No clear structure, and presentation very weak. Poor or no graphs. | Weak structure poor presentation.  Not useful or flawed graphs. | Satisfactory structure and presentation. Satisfactory graphs. | Very well structured and presentations with only minor limitations. Very good use of graphs. | Highly professional approach; excellent structure and graphs. |