

# Analysis and Design of Bio-Inspired Computation

## Introduction

Applications are invited for a fully-funded PhD studentship on the analysis and design of bio-inspired computation techniques such as evolutionary algorithms, genetic algorithms, ant colony optimisation and artificial immune systems which are widely used heuristic search techniques at the heart of artificial intelligence.

## Supervisor Bio

Professor Pietro S. Oliveto is Chair of the Algorithms research group. His main research interest is the rigorous performance analysis of bio-inspired computation techniques. He has successfully supervised PhD projects on the theoretical foundations of evolutionary computation, artificial immune systems, hyper-heuristics and automatic algorithm configurators.

## About the project

Bio-inspired meta-heuristics, such as genetic algorithms, ant colony optimisation or artificial immune systems are general purpose algorithms that mimic powerful mechanisms from nature such as the natural evolution of species or the collective intelligence of animals with the goal of solving complex optimisation problems. They have been applied to a broad range of problems in various disciplines with remarkable success. They are particularly useful in settings where limited knowledge about the problem is available (black-box optimisation) and evaluating candidate solutions is the only means of learning about the problem at hand.

However, the reasons behind their success are often elusive: their performance often depends crucially, and unpredictably, on design choices and parameters. Furthermore, given a class of bio-inspired algorithms it is unclear on which kind of problems it performs well and on which it performs poorly.

Two main strategies have been used to analyse the performance and behaviour of bio-inspired optimisation techniques: theoretical and experimental analyses. Theoretical analysis use mathematical techniques to rigorously estimate the expected time required by the algorithms to find a satisfactory solution for various optimisation problems. Experimental analyses are used to formulate hypothesis regarding behaviour and assess performance on particular problem instances. The aim of both strategies is to gain an understanding of the working principles of bio-inspired meta-heuristics, enable the assessment of parameter choices and design aspects, and ultimately guide towards the design of more powerful algorithms. In this PhD project the candidate will be guided by both the theoretical and experimental analyses literature for the understanding of the behaviour of established bio-inspired computing techniques and identify modifications leading to the design of better performing ones.

This studentship offers a valuable opportunity to work within this very active, challenging and exciting field of research at the intersection between theoretical computer science, machine learning and artificial intelligence.

The successful applicant will perform high quality research at the interface between bio-inspired computation and artificial intelligence. During the PhD studies, he/she will develop expertise in one or more promising research areas of his/her choice in this wide research area.

Possible topics include the analysis and design of algorithms in the following areas:

- a) Population-based meta-heuristics: highlighting their advantages over single-trajectory algorithms and/or the advantages of recombination over mutation-only algorithms

- b) Algorithm configurators: how to evolve the optimal parameter settings for the meta-heuristic
- c) Hyper-heuristics: how to evolve the meta-heuristic itself
- d) Genetic programming: how to evolve computer programs effectively

#### About the department / Research Group

The Department of Computer Science was established in 1982 and has since attained an international reputation for its research and teaching. In the 2014 Research Excellence Framework, 45% of the research in the department was recognised as internationally excellent in terms of originality, significance and rigour, and another 47% as internationally world leading. These results placed the department among the top 5 UK computer science departments for research excellence. The successful candidate will join the recently established and growing Algorithms group in the department with world-leading expertise in the theory of bio-inspired computation.

#### Key Words

Artificial Intelligence, Bio-Inspired Computation

#### Candidate Requirements

Applicants must have at least a 2.1 or above degree in Computer Science. Outstanding applicants from Mathematics, Physics and Engineering will also be considered and are encouraged to apply. The successful applicant must have excellent analytical and computational skills. He/She must be an excellent team player who can work independently and communicate well with others. If English is not their first language, they must have an IELTS score of 6.5 overall, with no less than 6.0 in each component. Strong mathematical and probability theory skills are recommended for the understanding of the theoretical literature. Excellent programming skills are required to deal effectively with expensive experimental setups

#### Funding and Eligibility

This Studentship will cover tuition fees at the UK rate and provide a tax-free stipend at the standard UK rate (currently £15,609 for 2021/22) for three and a half years. International students are eligible to apply, however will have to pay the difference between the UK and Overseas tuition fee. Funding is available for conference attendance and collaborative research visits to related organisations.