Natural Computation

Course Organisation

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Lectures

- Video lectures (10 main units (examinable),
  5 supplementary units plus 4 bonus units (non-examinable*)
- Slides are available also separately from the videos
- The course content will be available also as a script (includes both examinable and non-examinable content)
- Weekly meeting time to be agreed
  - e.g. Wednesday, 17:10: Q&A, discussion of special topics and coursework (50mins)

*Edinburgh marking schemes applies

Weekly online Q&A meeting

- Online Q&A & Discussion group
- First meeting in week 1: Course organisation
- Weeks 2-9: Q&A
- Last meeting in week 10: revision meeting
- Content:
  - Self-study questions
  - Discussion of coursework
  - General questions on lectures etc.

Self-study questions

- Exercises sheets will be available one week before the resp. week
- Solutions will be available in the following week
- Will include computational tasks
- Discussing and feedback in the online Q&A group
- Unmarked!

Coursework Assignment

- From 3th October to 14th November (6 weeks)
- Unmarked intermediate report can be submitted in the last week of October
- Will include
  - programming tasks (python)
  - testing a few variants of your program
  - statistical analysis
  - graphical representation
  - report
- Worth 40% of course mark

Quizzes

- Check for quizzes in Learn
- 10 quizzes of 10 questions each
- Starting in first week (first deadline: 27/09)
- One quiz per week (double quiz in week 10)
- Each quiz is life for at least 10 days
- Quizzes can be taken three times before deadline (last mark counts)
- Best 7 out of 10 quizzes enter the mark:

$$\text{points} = \frac{1}{7} \sum_{\text{best quizzes}}^{7} \#\text{correct answers per quiz}$$

- It's not very difficult to get 10/10 marks for this component (corresponding 10% of course mark)

Exam

- December diet
- 50% of course mark
- Questions
  - A set of simple problems, straight-forwardly answerable questions (similar to the quiz questions, but not MCQs)
  - Two options each of which includes
    - a theoretical question
    - an application-oriented question

"What do we need to know for the exam?"

- 'Open book' (a few sheets a paper can be taken into the exam hall)
- Basic forms of main algorithms (e.g. pseudocode)
- Explain how they work
- What can be done with them
- How to decide what algorithm to use
- How to combine algorithms
- Revision tutorial in week 10

Prerequisites

- Programming: Python will be used in tutorials and in coursework
  - some other languages can be used in the assignment, but templates will be made available only for python
- Computing: "the curse of dimensionality", algorithms
- It will be useful to revise some maths topics (see primer):
  - linear algebra: N-dim. space, hyperplanes, eigenvalues, eigenvectors
  - geometry: generalisation of spheres and cubes to higher dimensions
  - calculus: convergence, gradients, extremal values of a function
  - probability and statistics: correlation matrices, Bayes' rule, law of large numbers
- Biology, physics, chemistry, neuroscience ...: This courses is about natural computing, so it cannot hurt to have a good understanding of science and nature.

Natural Computation

comprises three classes of methods:

1. Those that employ natural materials (e.g., molecules, nanorobots) to compute (media),
2. Those that are based on the use of computers to synthesise natural phenomena (models) and
3. Those that take inspiration from nature for the development of problem-solving techniques (methods)*

adapted from http://en.wikipedia.org/wiki/Natural_computing

*We will mainly focus on this.

Overview

wk	Lecture	Supplement	CW	Q&A	Quiz
1	Optimisation	General intro.			⇓
2	Discrete algorithms	ACO		⇓	NAT
3	Continuous algorithms	Implementation		GA	GA
4	Genetic programming	NFL	⇓	PSO	PSO
5	Parameter settings	Theory of GA	⇓	GP	GP
6	Multiobj. optimisation	More algorithms	⇓	ACO	ACO
7	Hyperheuristics	Context	⇓	MHO	MHO
8	Applications	Comparison	⇓	MOO	MOO
9	MHO & neural networks	Robot swarms	⇓	Appl	Appl
10	Recent advances	Natural evolution		Revision	2 Qu.
T	50'	50'	20h	50'	10'
Σ	8h	2h	20h	8h	2h

Literature: General overviews

Short and useful: Wikipedia

Elaborate and well explained:

- El-ghazali Talbi: Metaheuristics – From Design to Implementation. Wiley 2009.
- Anthony Brabazon, Michael O'Neill, Seán McGarraghy: Natural Computing Algorithms. Berlin and Heidelberg: Springer, 2015.
- Patrick Siarry (Editor) Metaheuristics. Cham, Switzerland: Springer, 2016.

Comprehensive:

- L. N. de Castro: Fundamentals of Natural Computing: Basic Concepts, Algorithms, and Applications. Chapman & Hall, 2006. See also: Physics of Life Reviews 4: pp.1–36, 2007.
- G. Rozenberg, T. Bäck, J. N. Kok (Editors) Handbook of Natural Computing Springer, 2010.

Recommendations in blue.

In-depth studies (These are not reading recommendions)

- John R. Koza: Genetic Programming (1992) On the programming of computers by means of natural selection, MIT Press.
- Riccardo Poli, William B. Langdon, Nicholas F. McPhee (1992) A Field Guide to Genetic Programming. www.gp-field-guide.org.uk.
- Kenneth V. Price, Rainer M. Storn, Jouni A. Lampinen (2005): Differential Evolution. Springer.
- Thomas Weise (2009) Global Optimization Algorithms – Theory and Application –. Newest Version: http://www.it-weise.de/.
- Dario Floreano, Claudio Mattiussi (2008) Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies. MIT Press.
- Nazmul Siddique, Hojjat Adeli (2017) Nature-Inspired Computing. Physics- and Chemistry-Based Algorithms. CRC Press.
- Nelishia Pillay and Rong Qu (2018) Hyper-heuristics. Springer.
- Benjamin Doerr, Frank Neumann (2019) Theory of evolutionary computation. Springer.
- Neil Urquhart (2022) Nature Inspired Optimisation for Delivery Problems: From Theory to the Real World. Springer.
- Tome Eftimov & Peter Korošec (2022) Deep Statistical Comparison for Meta-heuristic Stochastic Optimization Algorithms. Springer.

Reading suggestions (and a few dissuasions)

Recommended (but not required):

- Melanie Mitchell: An Introduction to Genetic Algorithms. MIT Press, 1998. (excellent, but just one topic)
- Eric Bonabeau, Marco Dorigo and Guy Theraulez: Swarm intelligence. Oxford University Press, 1999. (natural science apporach)
- Chopard, B. and Tomassini, M., An introduction to metaheuristics for optimization. Springer, 2018. (good theory book)

Not really useful for a deeper understanding:

- Xin-She Yang: Nature-Inspired Metaheuristic Algorithms. Luniver Press 2010.
- Giancarlo Zaccone: Natural Computing with Python. BPB Publications, 2019.
- ~~Gerardus Blokdyk: Natural computing. A Clear and Concise Reference. 5STARCooks, 2022.~~

Lecture Script

Introduction to the Theory of
❧ Natural Computing ❧

Pros:

- Free of charge
- Regularly updated
- Exclusive for NAT & NAT-DL

Cons:

- Not finished
- Not practical
- Nothing but the lecture content (incl. non-examinable material)