Evolutionary Computation

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1 Seminar description

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Evolutionary computation (EC) is an umbrella term for a family of stochastic optimisation algorithms that take inspiration from Darwinian evolution theory. In a nutshell (and very generic) such algorithms maintain a multi-set/population of solution candidates for the optimisation problem at hand. This population evolves in an iterative manner by applying bio-inspired variation and survival-selection operators until some predefined termination criterion is met. Evolutionary algorithms (EAs) are general purpose solvers and have proven to perform exceptionally well in many (black-box) real-world applications, in the field of multi-objective optimisation. (Problem-tailored) EAs are also very successful in combinatorial optimisation. A great example for the latter is the Edge-Assembly-Crossover algorithm (EAX) for the well-known NP-hard Euclidean Travelling Salesperson Problem (TSP). EAX manages to find (close to) optimal solutions for TSP instances with thousands of notes within minutes or even seconds.

This block seminar course will be held in English, towards the end of the 2022/2023 winter semester. Enrolment is restricted to at most 20 Bachelor or Master students, preferably with a background in optimisation. Students will work in groups of two on different EC-related topics, including but not limited to evolutionary optimisation in the continuous and discrete domain, genetic programming, evolutionary multi-objective optimisation, principled performance assessment, and more recent EC-branches like evolutionary diversity optimisation (EDO) and quality diversity (QD). Each group will be assigned a paper from the research literature, which will serve as the starting point for an in-depth investigation of a specific topic; the results of this investigation will be presented in class and compiled into a report.

2 Seminar procedure

In an introductory *kick-off meeting* we will present our ideas on the seminar procedure. Students will be divided into groups of two by us using a semi-random process aimed at ensuring diversity and complementarity of experience within the groups. Each group will be assigned a recent publication from the field of Evoluitionary Computation, which serves as a starting point into the respective topic. The groups dive into the topic by performing literature search and compile a survey-like report giving an overview of the respective field. The results are presented in an oral presentation.

- The seminar will take place as a block-seminar in mid-September.
- 30 minutes talk (each student must contribute equally) plus additional 30 minutes of in-depth discussion.
- Seminar report: 20 pages max, using the LaTeX template provided by us, including references, figures etc. A statement outlining the contributions of each team member is mandatory and will be used as one basis for assessment.

3 Oral Presentation

- Use the provided LaTeX-template (see website) for the presentation slides (we do not allow Power-Point presentations).
- Do not lose yourself in unimportant details too much.
- Keep the time limit (30min; a little less is OK, a little more is *not* OK).
- Each group member should participate equally.

4 Report

- Note that the paper assigned to your group is *not necessarily the most relevant*. We expect you to take it as a 'first clue', deep-dive into the literature and compile the most relevant aspects. Discovering and deciding which papers are important is part of your work. Note also that not everything has to be covered in full detail. It is up to the group to decide which papers and content is most relevant.
- Use the provided LaTeX-template (see website) for the final report and submit in PDF-format (we do not accept MS-Word reports).
- Stick to the page limit: 20 pages using the prescribed format, including references, figures etc.
- A report contains introduction, conclusion and bibliography among other sections.

5 Criteria for successful completion

- Preparation of a seminar report in LaTeX (max. 20 pages, using the prescribed format, PDF)
- 30 minute presentation + 30 minutes discussion
- Meeting all deadlines
- Attendance of all mandatory meetings
- **Grading**: 60% report, 30% presentation incl. answers to questions and 10% participation in discussions on other presentations.

6 Important Dates

- Kickoff meeting: 24 October 2022
- Progress update (via e-mail, bullet points are OK, but do give us some details): **18 November 2022 6pm CEST** (hard deadline!)
- Final report due (PDF via e-mail): **27 January 2023 6pm CEST** (hard deadline!)
- Block seminar: February or March 2023 (tba)

7 Groups and topics

Group assignment performed by random permutation while making sure that no two Master students are assigned the same group. I. e., each group has at most one Master student.

A very good introduction into the basic principles of evolutionary computation is given by Eiben & Smith [5] (google it; can be downloaded for free). I strongly recommend to work through Chapters 1 to Chapter 5.3 to get a basic understanding of the fundamentals.

PAR Simon Paul Levin Mainz, Elias Müllers
Topic: Parameter Control
A.E. Eiben and S.K. Smit. "Parameter tuning for configuring and analyzing evolutionary algorithms". In: *Swarm and Evolutionary Computation* 1.1 (2011), pp. 19–31. ISSN: 2210-6502. DOI: https://doi.org/10.1016/j.swevo.2011.02.001

DP Brian Schiller, Philipp Christoph Schneider
Topic: Diversity Preservation
Maury Meirelles Gouvêa Jr. and Aluizio Fausto Ribeiro Araújo. "Diversity-Based Adaptive Evolutionary Algorithms". In: *New Achievements in Evolutionary Computation*. Ed. by Peter Korosec. Rijeka: IntechOpen, 2010. Chap. 1. DOI: 10.5772/8046

EDO Dominic Wittner, Tobias Richter

Topic: Evolutionary Diversity Optimisation

Jakob Bossek and Frank Neumann. "Evolutionary diversity optimization and the minimum spanning tree problem". In: *GECCO*. ACM, 2021, pp. 198–206

NSQD Dominik Lazar, Adam Haman

Topic: Novelty Search & Quality Diversity

Justin K. Pugh, Lisa B. Soros, and Kenneth O. Stanley. "Quality Diversity: A New Frontier for Evolutionary Computation". In: *Frontiers Robotics AI* 3 (2016), p. 40

B Erik Schwarz, Nadim Khaded Nezar Adham

Topic: Benchmarking of Stochastic Optimisation Algorithms

Thomas Bartz-Beielstein et al. *Benchmarking in Optimization: Best Practice and Open Issues*. 2020. DOI: 10.48550/ARXIV.2007.03488

MOO-1 Jakob Leonhard Kapfenberger, Ritabrate Sanyal

Topic: Dominance-Based EMOAs

K. Deb et al. "A fast and elitist multiobjective genetic algorithm: NSGA-II". in: *IEEE Transactions on Evolutionary Computation* 6.2 (2002), pp. 182–197. DOI: 10.1109/4235.996017

MOO-2 Daniel Tebart, Edwin-Daniel Özdemir

Topic: Decomposition-Based EMOAs

Qingfu Zhang and Hui Li. "MOEA/D: A Multiobjective Evolutionary Algorithm Based on Decomposition". In: *IEEE Transactions on Evolutionary Computation* 11.6 (2007), pp. 712–731. DOI: 10.1109/TEVC.2007.892759

MOO-3 Jana Lemke, Marc Flemming Thiemann

Topic: Haman Many-Objective Optimisation

Shelvin Chand and Markus Wagner. "Evolutionary many-objective optimization: A quick-start guide". In: *Surveys in Operations Research and Management Science* 20.2 (2015), pp. 35–42. ISSN: 1876-7354. DOI: https://doi.org/10.1016/j.sorms.2015.08.001

EA-TSP Marko Goldschmidt

Topic: EA for the Travelling Salesperson Problem

Yuichi Nagata and Shigenobu Kobayashi. "A Powerful Genetic Algorithm Using Edge Assembly Crossover for the Traveling Salesman Problem". In: *INFORMS Journal on Computing* 25.2 (2013), pp. 346–363. DOI: 10.1287/ijoc.1120.0506