Supervisor’s evaluation of

PhD candidate Lukáš Bajer

I know Lukáš Bajer for nearly 10 years because before his PhD studies, I already supervised his master thesis. Most of that time he was also a part-time student employee of our institute, in some Czech Science Foundation projects of mine or of some of my colleagues, so that we really had a chance to meet very frequently. Therefore, I’ll give comments not only on the submitted thesis, but even more on Lukáš’s evolution during those 10 years, which substantially influenced the genesis of his thesis and its content.

Lukáš’s general area of interest was optimization, especially evolutionary optimization. At the beginning of his doctoral studies, I directed him towards copulas and their applicability in estimation of distribution algorithms (EDA) because this topic was emerging exactly in that time and because I was familiar with copulas from data mining. During his first PhD year, he got acquainted both with EDA and with different kinds of copulas. Simultaneously, because his master thesis dealing with evolutionary optimization using surrogate modelling based on radial basis functions (RBF) networks was clearly above average, he prepared a conference paper presenting the master thesis results for the LNCS conference IDEAL 2010. He succeeded in getting the paper accepted and after the conference, he was excited receiving an e-mail from the International Journal of Neural Systems suggesting him to consider preparing a substantially extended version of the conference paper for their journal. I explained him that all conference participants may have received that e-mail and that in my opinion, his master thesis research has been neither original enough nor mature enough for a journal publication. Then Lukáš returned to copulas and EDA and prepared his first conference publication concerning this topic (cf. Chapter 4 of the thesis). However, as he received the e-mail from the International Journal of Neural Systems inviting him to submit an extended version of his IDEAL conference paper once more, 6 months later, I gave up and let Lukáš to spend one year further elaborating and more extensively testing his RBF-based surrogate modelling approach for the journal submission (essentially reproduced in Chapter 6 of the thesis), which was nevertheless rejected due to insufficient maturity for the journal.

After Lukáš’s side-step to the master thesis topic failed, we needed to rethink the schedule of his doctoral studies. In this context, Lukáš revealed that more important than the speed of his progress is for him to use approaches that he perceives as impressive and state of the art, especially from the point of view of real-world applications. In connection with preparing the paper about evolutionary optimization with RBF surrogate modelling, he was much impressed
by Bayesian optimization based on Gaussian processes, especially by the Efficient Global Optimization algorithm (EGO), and decided to make an advancement of that algorithm the next step of his research (cf. Chapter 8 of the thesis). Fortunately, he has not completely left copulas and helped me with my own research in that area. This brought him his first journal publication, in the prestigious IEEE Transactions on Knowledge and Data Engineering (essentially reproduced in Chapter 3 of the thesis). Although he was only the 2nd author, his contribution was important and substantial (I estimate it to represent 40% of the efforts spent for the published research).

Lukáš’s first idea was to improve EGO through a more sophisticated method sampling (cf. Chapter 4 of the thesis). After a year of work in that direction, he presented his results at the Genetic and Evolutionary Computation Conference (GECCO) 2013. However, several other papers presented at that conference have clearly shown that Gaussian processes are more efficient if used in synergy with some evolutionary algorithm, in a similar way like Lukáš used RBF networks in his master thesis. In this way, Lukáš dialectically returned back to surrogate modelling, though with RBF networks replaced through the more advanced and theoretically better founded Gaussian processes.

Whereas his RBF-based surrogate model in the master thesis was developed for a specific genetic algorithm that I elaborated in the application area of materials science, we decided to develop the surrogate model based on Gaussian processes for some generally used evolutionary algorithm. Lukáš has chosen the covariance matrix adaptation evolution strategy (CMA-ES) to this end, which has been considered the state-of-art evolutionary approach to black-box optimization for more than 15 years. This promised any contribution further improving CMA-ES, such as an improvement through a surrogate model on some conditions decreasing the number of the evaluations of the black-box fitness functions more than other surrogate models, to have a great impact. On the other hand, it is challenging to achieve any such contribution because the number of researchers attempting to further improve CMA-ES is considerable, in particular also the number of those who develop more advanced surrogate models for it. That explains why Lukáš needed nearly three more years for really achieving such a contribution. This contribution is the surrogate model based on a Gaussian process trained twice within each generation, which was first presented at the prestigious conference PPSN 2016 and which, one year later, has won the first place among the 13 algorithms participating in the expensive single-objective track of the prestigious Black-Box Optimization Competition at GECCO 2017. Finally, the performance of the new surrogate model has been rigorously evaluated through statistical testing on 24 commonly used benchmark functions in a comprehensible investigation of 8 improvements of CMA-ES through surrogate models, compared with the most common version of CMA-ES without surrogate modelling, and with 3 other methods commonly employed for black-box optimization. That investigation has been presented in his second journal paper (essentially reproduced in Chapter 9 of the thesis), of which he was the main author, and which was submitted to the prestigious journal Evolutionary Computation just before Lukáš started to write his thesis. Needless to say, the 4 years between Lukáš’s switching to the research into surrogate modelling for CMA-ES based on Gaussian processes and submitting the paper into Evolutionary Computation included also several attempts bringing no success. Chapter 10 of the thesis describes the theoretically best founded among them, Gaussian processes ordinal regression, inspired by the invariance of CMA-ES with respect to monotone transformations.
Due to his interest in research into state-of-art approaches (and partially also due to the duration of his PhD studies), Lukáš has an among PhD students above-average number of highly recognized citations:

- WOS citations – 21
- Scopus citations – 57

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